

FINAL REPORT

# **Study of Fitting and Fairing Aids of U.S. Shipyards**

August 1984

By

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710 Front Street  
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Under:

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## **FOREWORD**

A study of fitting and fairing aids in the U. S. shipbuilding industry is really a study in the degree of accuracy and dimensional control of the components that makeup the total ship. Fitting and fairing are terms used to describe actions taken during the assembly of the components, and corrective actions taken as a result of material distortions due to stresses in the material caused by forming, burning, and welding. The use of these aids is in proportion to how early in the fabrication sequence distortions are introduced, and to what extent these distortions are incurred.

This document is an attempt to list and categorize fitting and fairing aids used in the U.S. shipbuilding industry. It also provides implementation rationale for a select group of aids which are considered highly effective.

This document was written for shop and area managers, foremen, and engineers interested in methods and devices for handling, fitting, and fairing problems developed by their counterparts throughout the industry. The need for greater accuracy, and the reduction for the need of these methods, must be emphasized. Fitting and fairing must be performed to increase production, and this can be achieved through the use of fitting to support welding, and by avoiding dependence on welding to compensate for inaccurate fitting.

## ACKNOWLEDGEMENTS

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The cooperation extended to the study teams by all the participating shipyards and fabricators is greatly appreciated. The information provided by the participants forms the heart of this report.

Special appreciation is expressed to the following fitting, welding, welding engineering and graphic arts personnel for their time and effort in participation in this study.

Todd, <i>L.A.</i>	NASSCO	Newport News Shipbuilding
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Thompson Metal Fab., Inc.  
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A subsidiary of Harder Mechanical Contractors, Inc.

Trusco Tank, Inc.  
San Luis Obispo, California

## **1.0 INTRODUCTION**

### **1.1 Background**

The use of fitting and fairing aids has been and will continue to be an integral part of shipbuilding. Fitting and fairing aids were in use when the ancients built the first wooden ships. Since then, the methods used for fitting and aligning for fairing purposes have changed. Over the past one hundred years, materials and fabrication methods have changed dramatically.

In current day ships, building materials are mainly ferrous alloys. Non-ferrous metals, composites and wood are used in a small portion of the total vessel tonnage being built. All of these materials have flaws, inaccuracies, and stresses which will manifest themselves during the fabrication process as distortions of one sort or another. This, and the need to hold and align components, create the basic need for fitting and fairing aids.

It may be said that a fitting and fairing aid is a method or device used to hold or align (or both) two or more parts in a predetermined location. They may also be used to correct distortion while assembling components of structures, and the structures themselves. The ideal situation would be to use the minimum number of aids possible, but unfortunately, inherent flaws in the materials and other influencing factors seem to prohibit this.

It is important to have a knowledge of the available aids in order that an intelligent choice may be made for any particular application. Current technology available to the shipyards, such as line heating, can dramatically increase the accuracy of parts, assemblies, and overall fabrication. Use of such technology should decrease the need for fitting and fairing while increasing productivity.

### **1.2 Current Problems in Fabrication**

The problem of inaccuracy is many-faceted and begins before the material enters the yard.

#### **1.2.1 FOUNDRY AND MILL**

Problems start with the way many materials are made. Stresses from rolling mills and heat treatments can cause problems during the fabrication process. Edges and surface conditions are not always as they should be and need to be checked when materials enter the shipyard. Mill tolerances are often excessive and can add up during fabrication if not found before the material is used. The cumulative effect of this may result in excessive localized stress and distortion.

#### **1.2.2 STORAGE AND HANDLING**

Storage and handling of such materials as plate, pipe, shapes and castings can have a deleterious effect on surface condition and dimensional accuracy if done improperly. Problems occur when material is handled roughly or misused while in storage.

#### **1.2.3 BURNING AND CUTTING**

Burning or cutting operations can greatly increase the accuracy of assemblies if performed correctly. The heat of cutting may cause shrinkage and other distortions which must be monitored and offset. Edge condition must be held to specifications or fitting and welding time will be increased.

## **1.2 Current Problems in Fabrication (Cont'd)**

### **1.2.4 FORMING AND SHAPING**

When material is mechanically formed on rolls or similar equipment, deformation results. This causes stresses which will in turn cause distortion when stresses are relieved by the heat of welding or cutting, removal of portions of the material and any heat treatments. Other than forming parts by line heating, there is little that can be done to eliminate or reduce stresses set in by mechanical forming. All operations must be closely watched to ensure accuracy.

### **1.2.5 FITTING AND WELDING**

Stresses induced by fitting restraints, large gaps and welding are well known. These stresses result in distortion and deviation from design. These problems can be reduced by obtaining precise fitting, reducing the amount of welding and sequencing welding to minimize distortion.

## **1.3 Evolution of the Study**

The problems encountered during fabrication of ship assemblies are well known and shipyards in the U.S. deal with these continually. Because these problems are shared by all shipyards, this study was proposed to document those devices and methods being used by U.S. shipbuilders to combat these problems, and, where feasible, to recommend areas for improvement.

## **2.0 SCOPE**

This study documents fitting and fairing aids as currently used in U.S. shipyards. Also included is a select group of other U.S. fabricators.

### **2.1 Objective**

The overall objective was to review the methodology for use of fitting and fairing aids and assess the potential for improving the accuracy of fitting resulting in reduced costs for materials, energy and labor by introducing the most advanced available techniques suitable to the individual yards.

## **3.0 TECHNICAL APPROACH**

The methodology used to perform this study was as follows.

### **3.1 Review of Parent Shipyards**

Both Todd, L.A. and NASSCO shipyards were reviewed to determine the data requirements to best meet the objectives of this study. These reviews consisted of yard surveys (noting fitting and fairing methods and devices) and joint meetings to discuss and organize the study format.

### **3.2 Questionnaire**

The result of the parent yard reviews was the development of a questionnaire (see Figure 1). This questionnaire was sent to the participating shipyards to solicit data response. The questionnaire approach did not yield satisfactory results and was abandoned.

### **3.0 TECHNICAL APPROACH (Cont'd)**

#### **3.3 Shipyards and Other Companies Visited**

To obtain the needed information lacking from the questionnaire responses, yard visits were made. These visits generally consisted of discussions with fitting, welding and welding engineering personnel and yard walk-through surveys.

#### **3.4 Data Evaluation**

Data was organized and evaluated for incorporation into this report. Data in written form, as well as photographs and illustrations was obtained, each revealing methods, techniques and devices used for fitting and fairing.

#### **3.5 Recommendation Development**

From the information obtained, conclusions were drawn and recommendations made as to the most cost-effective methods and devices to use, and for possible future studies that might prove profitable to the industry to improve fitting and fairing accuracy and standardization.

### **4.0 FITTING AND FAIRING AID CATEGORIES**

The fitting and fairing aid devices documented herein are classified by their primary method of mechanical advantage in their design. Some of the aids shown use a combination of methods for force application.

- Wedge Devices
- Threaded Devices
- Hydraulic Devices
- Pneumatic Devices
- Gear-Pulley Devices
- Magnetic Devices
- Strongbacks
- Padeyes, Stays and Cables
- Jigs, Mocks and Fixtures
- Specialized Devices

# **FITTING AND FAIRING AIDS**

## **Questionnaire**

### **1. Panel Line**

- A) Deck Plating – What aids are used?
- B) Bulkheads – What aids are used?
- C) Stiffeners – What aids are used?

### **2. Subassembly**

- A) What type of jigs are used?
- B) What aids are used for attaching to jigs?
- C) What aids are used to attach members within assemblies?

### **3. Erection**

- A) What aids are used to support hull sections (e.g., loose bulkheads and side shell)?
- B) What aids are used to attach complete units/modules to each other?

### **4. Name, describe, sketch and/or photograph aids, other than traditional (e.g., dogs, wedges) types, which are manufactured for inhouse use.**

### **5. Does the type/method of welding affect the type of fitting aids? If so, to what extent'?**

### **6. What aids do you use when working: carbon steels, low-alloy, high-yield quenched and tempered steels (HY-80/HY- 100), aluminum or other metals?**

### **7. What type of fairing is used before erection, and to what extent?**

### **8. Are automatic and/or semi-automatic aids used instead of traditional aids? Describe and illustrate or provide photographs.**

### **9. Name your most specialized aids and state their applications. Describe and illustrate or provide photographs.**

### **10. Do you have any added questions/suggestions that would benefit this study? State them.**

**Figure 1. Questionnaire**

## WEDGE DEVICES

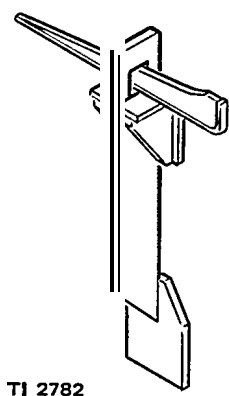
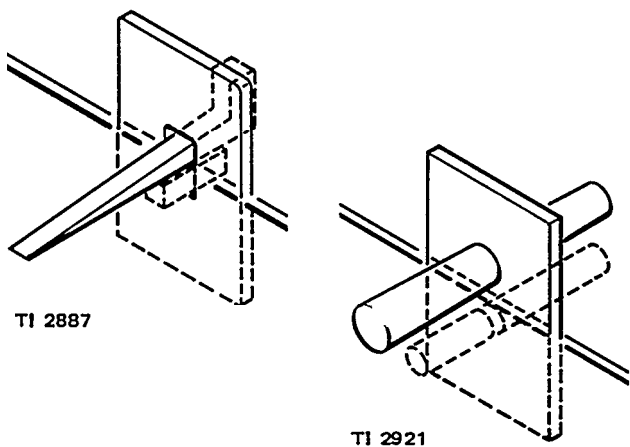
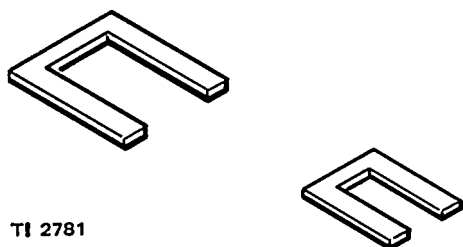
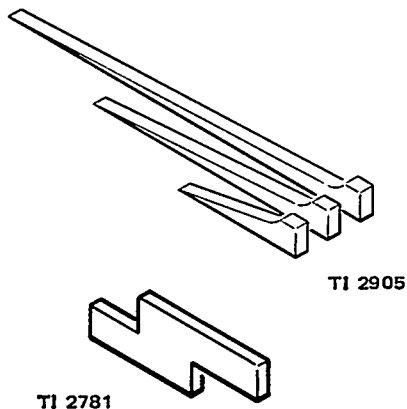
**WEDGE**, a piece of hard material, as wood or metal, tapering from a thick board to a thin edge that can be driven or forced into a narrow opening. Shipyard wedge configurations are usually made from one-inch-thick steel plate and are typically, 12 and 17 inches in length.

**STEP-CUT DOG**, also known as dog, a metal device used for holding or backing the force applied by a wedge or other tool. This device is attached by welding. Shipyard uses include erecting and aligning hull deck and bulkhead plating.

**WELD-ON SADDLE**, also known as "U"-dog, yoke and hairpin, a "U" or "L" shaped metal device used in conjunction with a wedge to straddle and hold one part to another. Shipyard uses include attachment of stiffeners to plate material.

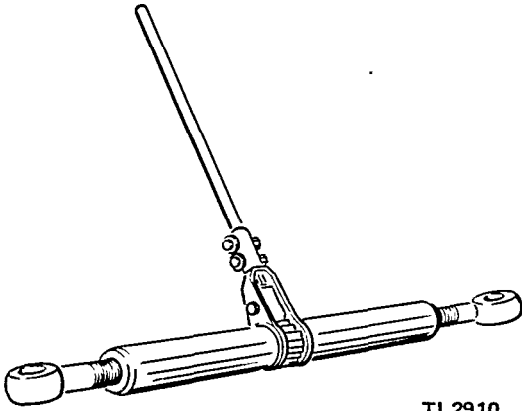
**YOKE & PIN**, also known as clip and wedge, a flat metal plate with an oblong hole, used in conjunction with wedges or bull pins to align edges of plate. Shipyard uses include deck and hull plate alignment.

**PULLDOWN**, a metal device welded or mechanically fastened to the part at one end and slotted at the other, used in conjunction with a wedge and anchor clip to pull one part toward another. Shipyard uses include pulling deck or shell plating and other components together.

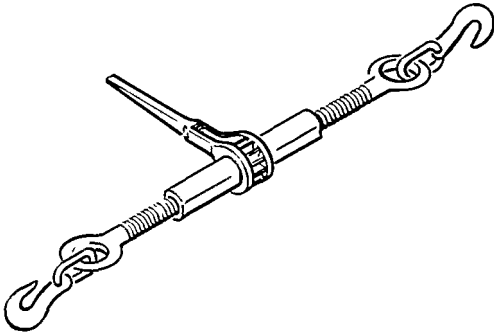


**THREADED DEVICES**

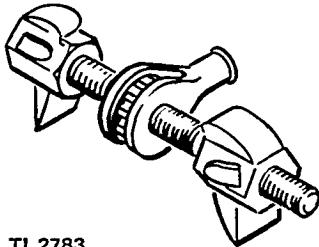
**PUSH-PULL JACK**, also known as steamboat jack and ratchet jack, a device having a ratcheting sleeve with opposite internal threads at each end or with an internal thread at one end and a swivel at the other. The effective length of the device can be changed by rotating the sleeve or swivel. Shipyard uses include areas where short reach or stroke is required in pulling parts together.



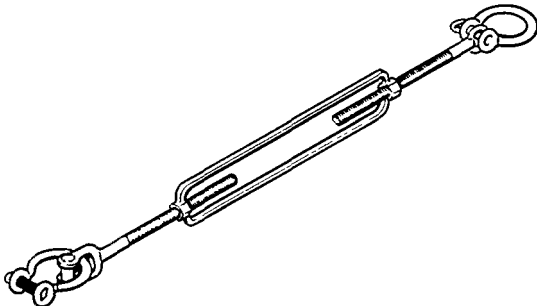
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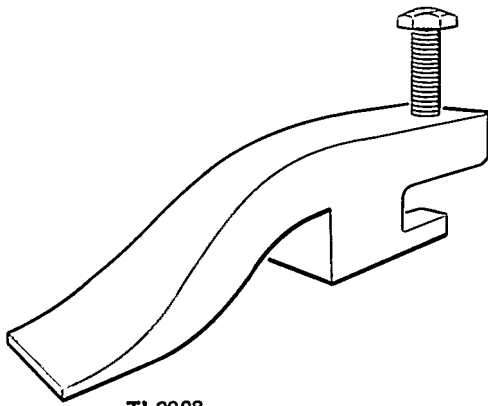


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**TURNBUCKLE**, a device having a metal loop or sleeve with opposite internal threads at each end or with an internal thread at one end and a swivel at the other. The effective length of the device can be changed by the sleeve or swivel. Shipyard uses include pulling together cable, stays and other devices to hold and align parts.

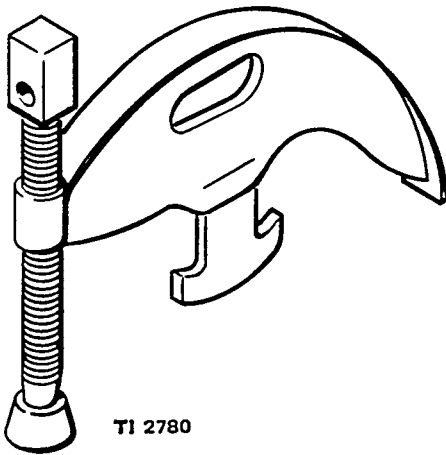
## THREADED DEVICES

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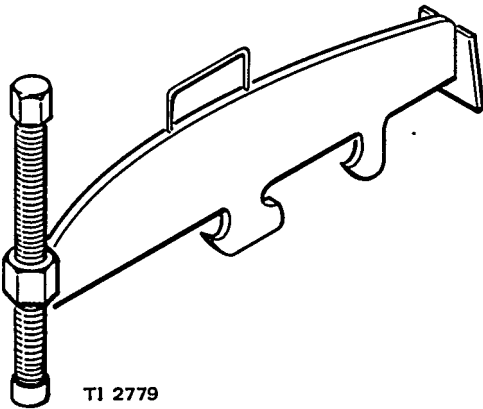


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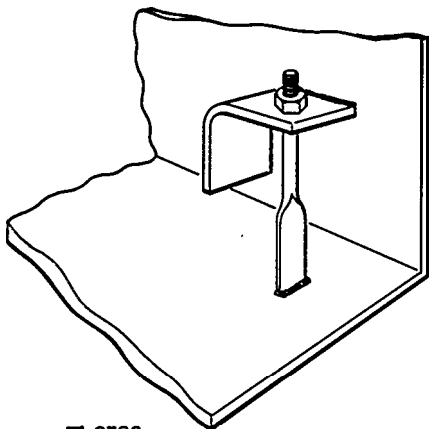
**JACKING CLAMP**, any number of devices which are hooked or welded having a screw at one end to apply force for aligning and fairing. Shipyard uses include fairing and aligning plate and occasionally used to clampdown stiffeners.



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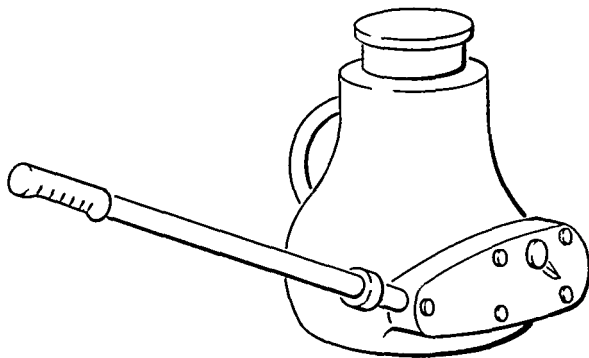
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**CLIP AND BOLT**, a device consisting of an angle support and a headless bolt, and used to pull parts toward each other. The angle support and bolt can be welded or mechanically fastened. Shipyard uses include pull bulkhead and stiffener-to-plate or deck.



## HYDRAULIC DEVICES

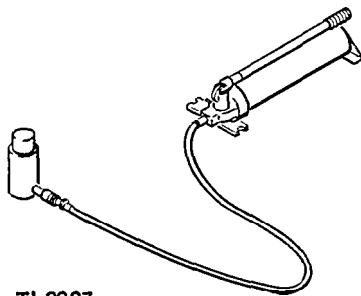
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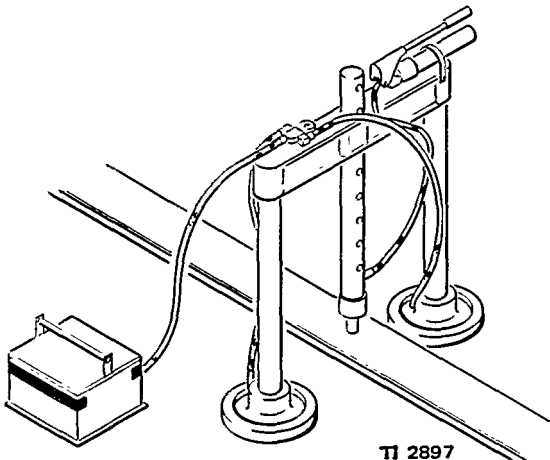
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**HYDRAULIC JACK**, also known as buda jack and bottle jack, a hydraulic and geared device having a single or double acting cylindrical piston used for hoisting or lifting. Shipyard uses include fairing, lifting and holding parts together that require short reach or stroke.

**PORTABLE HYDRAULIC RAM**, also known as Ports-power and Enerpack, a hydraulic device having an oil reservoir and a single or double acting cylindrical piston, used for lifting, pushing and holding parts together, Shipyard uses include fairing, lifting, aligning and holding structural parts and equipment. Used where short reach or stroke is required and in conjunction with other devices for fitting and fairing.

## PNEUMATIC DEVICES

4.4



TI 2897

**VACUUM SADDLE**, also known as vacuum jacking clamp, an air operated device having suction pads for gripping relatively smooth surfaces and a "U" or "L" shaped metal structure for straddling and holding parts together. This device is used in conjunction with a screw and thread or hydraulic ram for applying pushing force. Shipyard uses include stiffener-to-plate attachment.



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## GEAR-PULLEY DEVICES

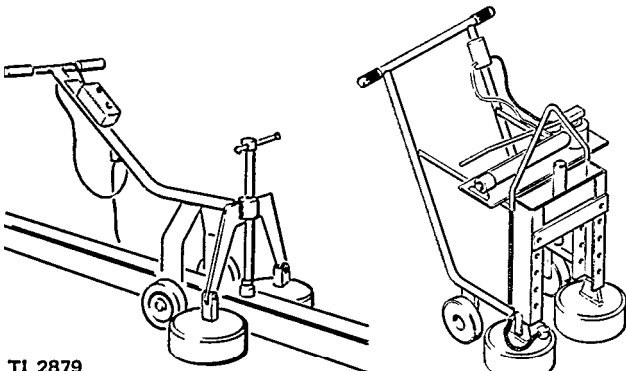
4.5

**CHAINFALL**, also known as chain hoist, a device having gears and pulley(s) and operated by chain to obtain mechanical advantage in lifting or pulling. Shipyard use includes areas where long reach or stroke is required in pulling parts together.

**COME-ALONG**, a device having a ratcheting gear-pulley arrangement to change the effective length of a chain for lifting or pulling. Shipyard use includes pulling parts and assemblies together.

## MAGNETIC DEVICES

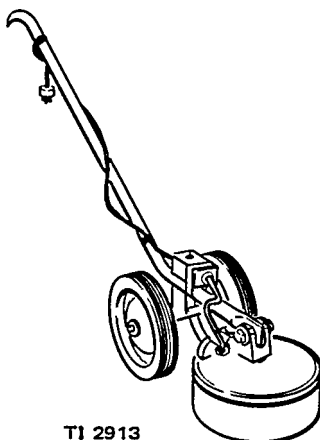
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**MAGNETIC SADDLE**, also known as magnetic jacking clamp, a device employing an electrically induced or permanent magnetic field(s) and a "U" or "L" shaped metal structure for straddling and holding ferrous metal parts together. This device is used in conjunction with a screw and thread or hydraulic ram for applying pushing force. Shipyard uses include stiffener-to-plate attachment.



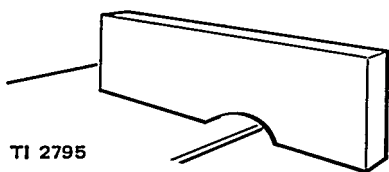
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**FITTING MAGNET**, a device employing an electrically induced magnetic field(s) for drawing ferrous metals together. Shipyard uses include aligning and holding flat plate together for joining.

## STRONGBACKS

**STRONGBACK**, any number of devices used to restrain applied forces and/or hold alignment. These devices may be welded or mechanically fastened and are used with many other tools for applying forces to parts. Shipyard uses include aligning, restraining, holding and fairing plates and structural components.

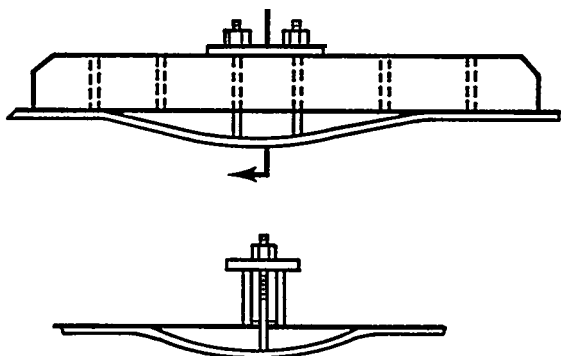
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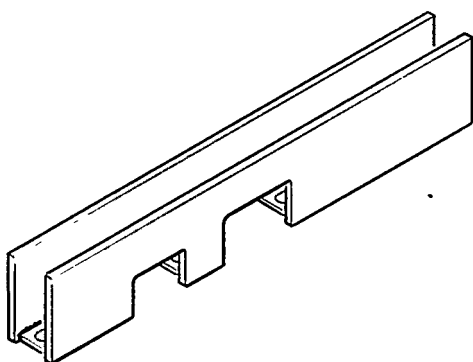
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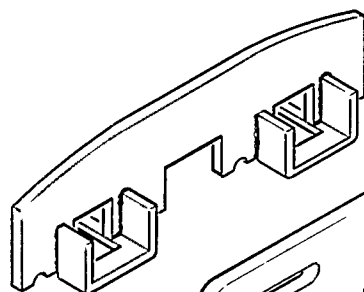
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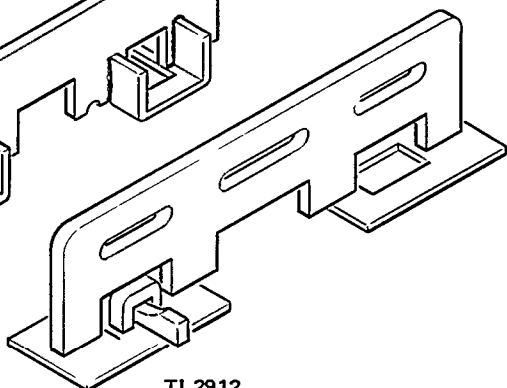
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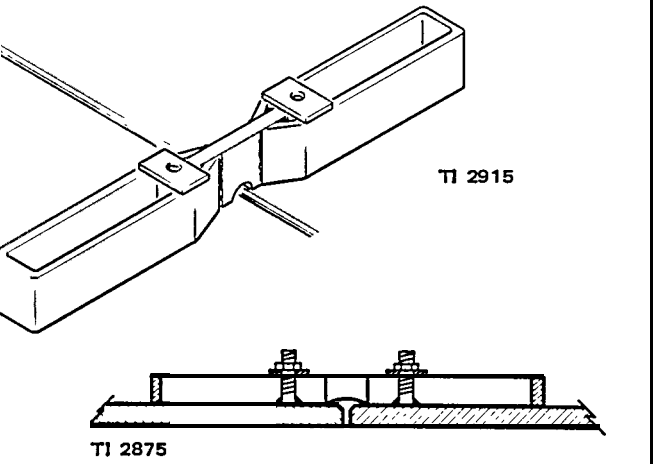
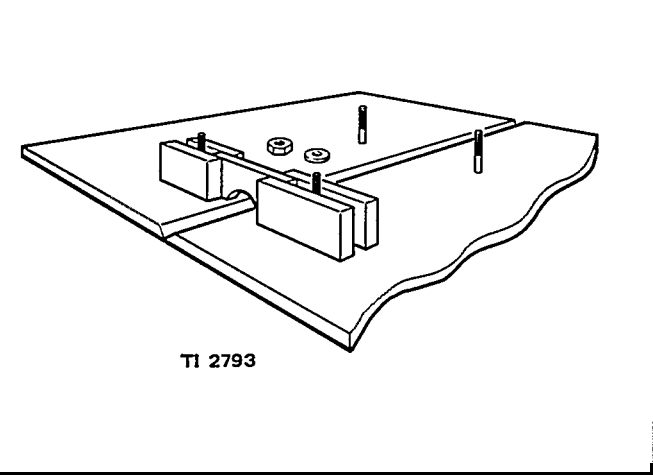
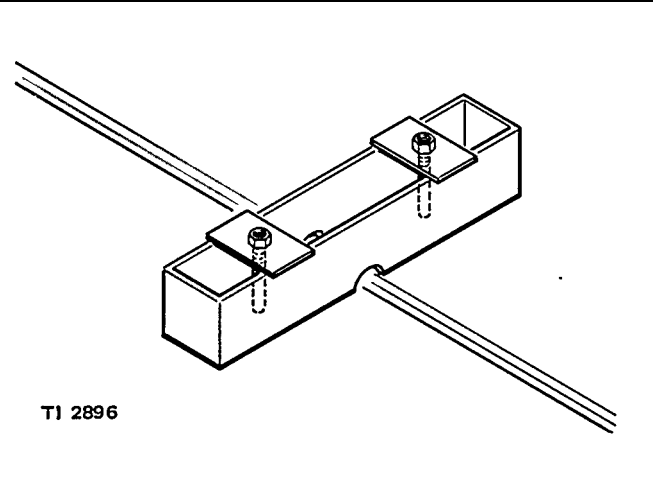
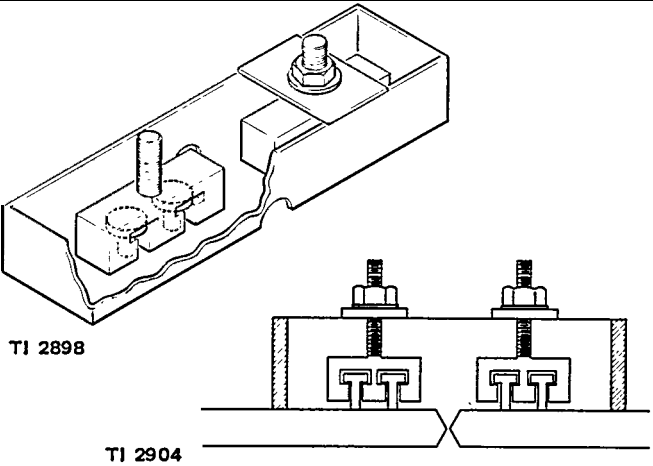


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**STRONGBACKS**

4.7

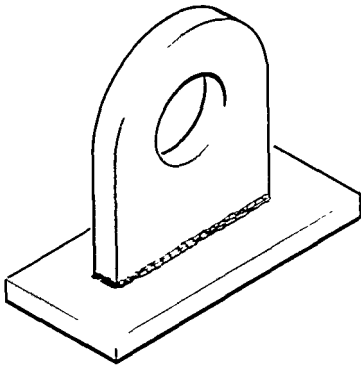


## PADEYES, STAYS AND CABLES

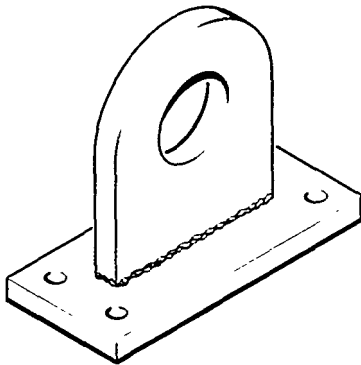
4.8



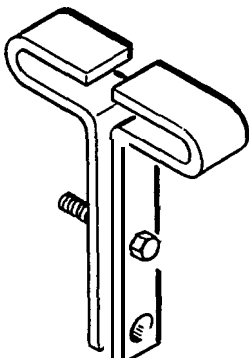
TI 2781



TI 2923



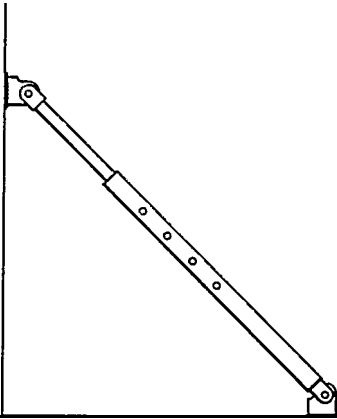
TI 2924



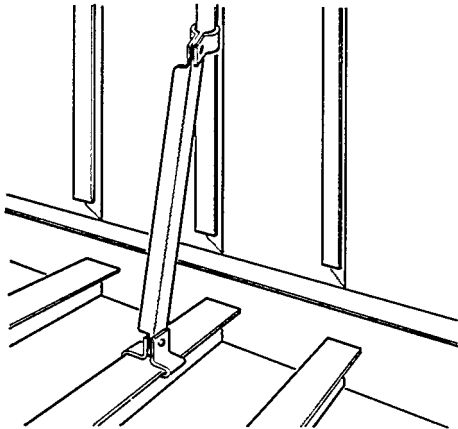
TI 2925

## PADEYES, STAYS AND CABLES

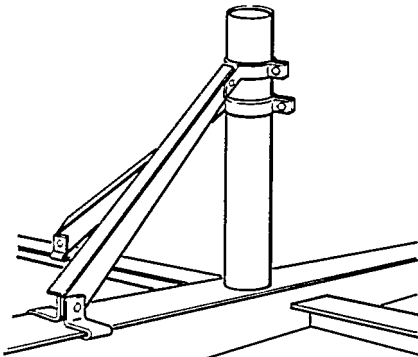
4.8



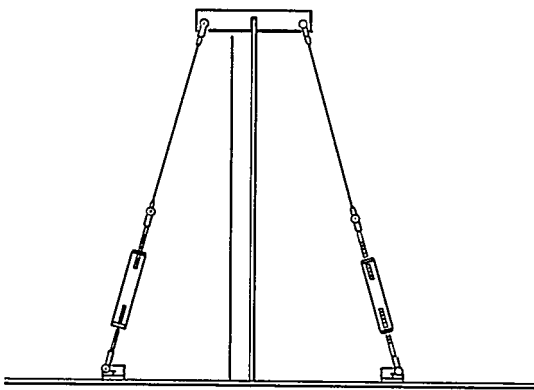
TI 2927



TI 2876



TI 2788



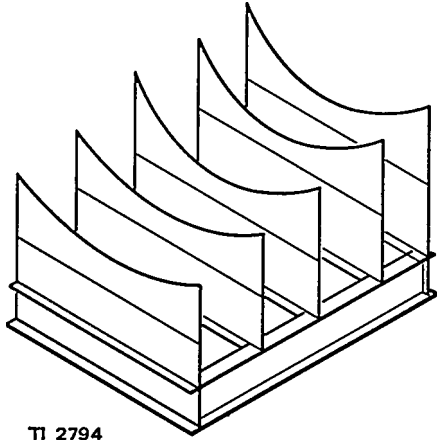
TI 2948

**STAY**, a strip of stiffening material used to hold, prop and/or support parts. This device can be welded or mechanically fastened. Shipyard uses include support and bracing of bulkheads and other assemblies to other parts.

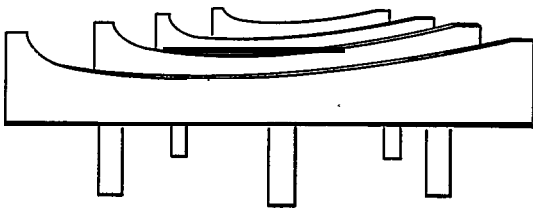
**CABLE**, a wire bundle or rope with means for attaching ends, used for lifting, pulling and holding parts. This device is normally attached by mechanical means to other fitting and fairing aids. Shipyard uses include lifting, supporting and transmission of pull forces for working components.

## JIGS, MOCKS AND FIXTURES

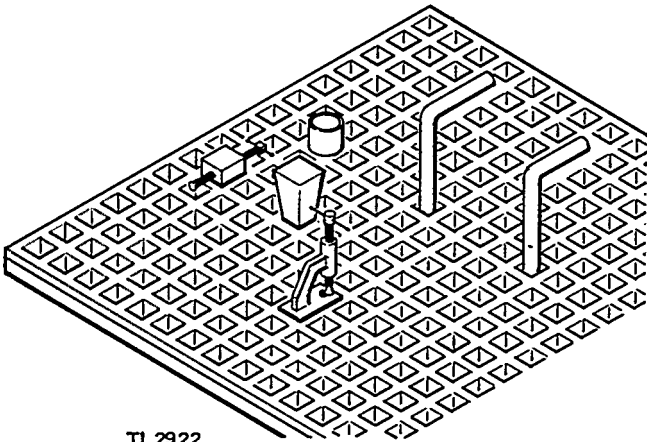
4.9



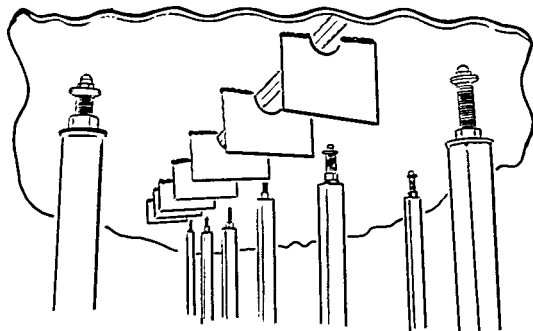
TI 2794



TI 2929



TI 2922

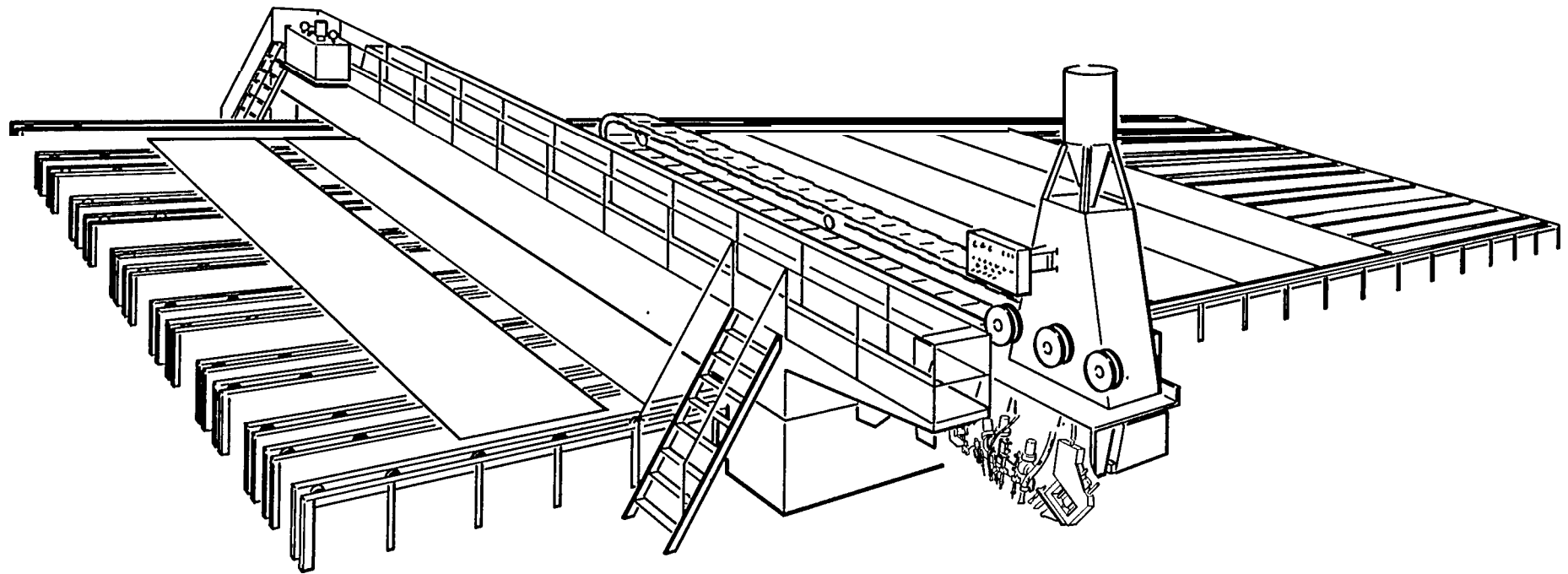


TI 2926

**MOCK**, a device which imitates the shape of an object for reference or support. Shipyard uses include holding hull shape and supporting units.

**FIXTURE**, a device used to hold, position and/or align a workpiece for an operation or process. Shipyard uses include assembly, subassembly, foundation and part fabrication.

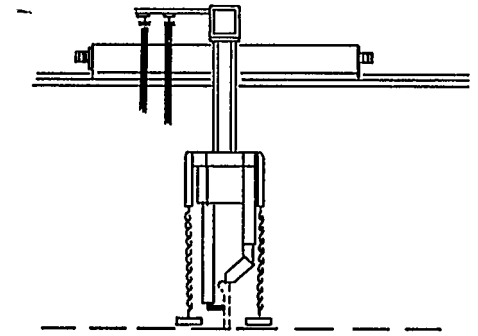
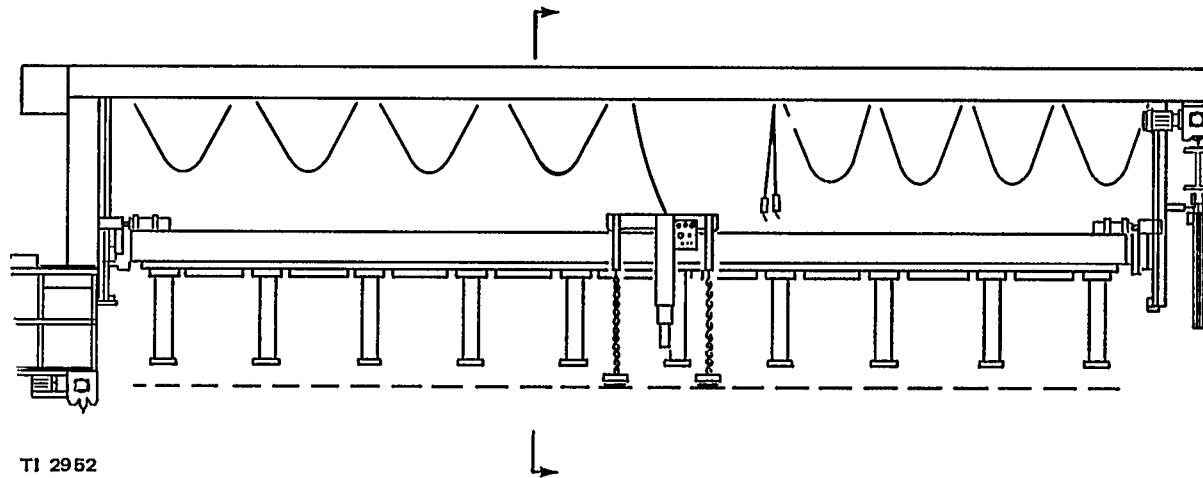
**JIG**, a device used to guide a tool; a template. Shipyard uses include pin tables and other devices for assembly of foundations, bulkheads, assemblies and parts. Jigs are often incorporated into fixtures.



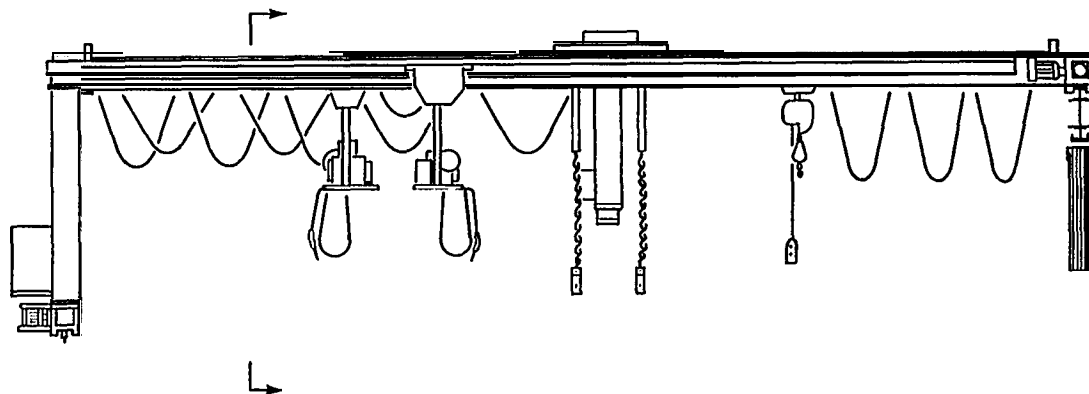
T1 2950

**ONE-SIDE WELDING SYSTEM**, a system which consists of a heavy structural frame, hydraulic, magnetic or pneumatic clamping rams, plate positioning and/or feeding conveyors, weld backing bar and welding equipment. Shipyard use is for panel line butt welding of plate into large blankets.

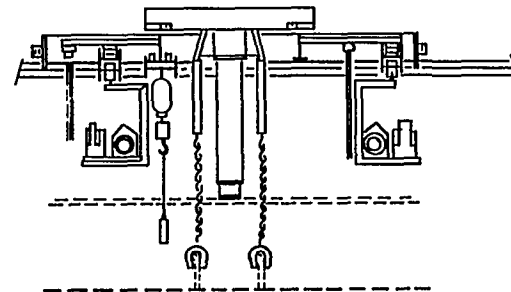




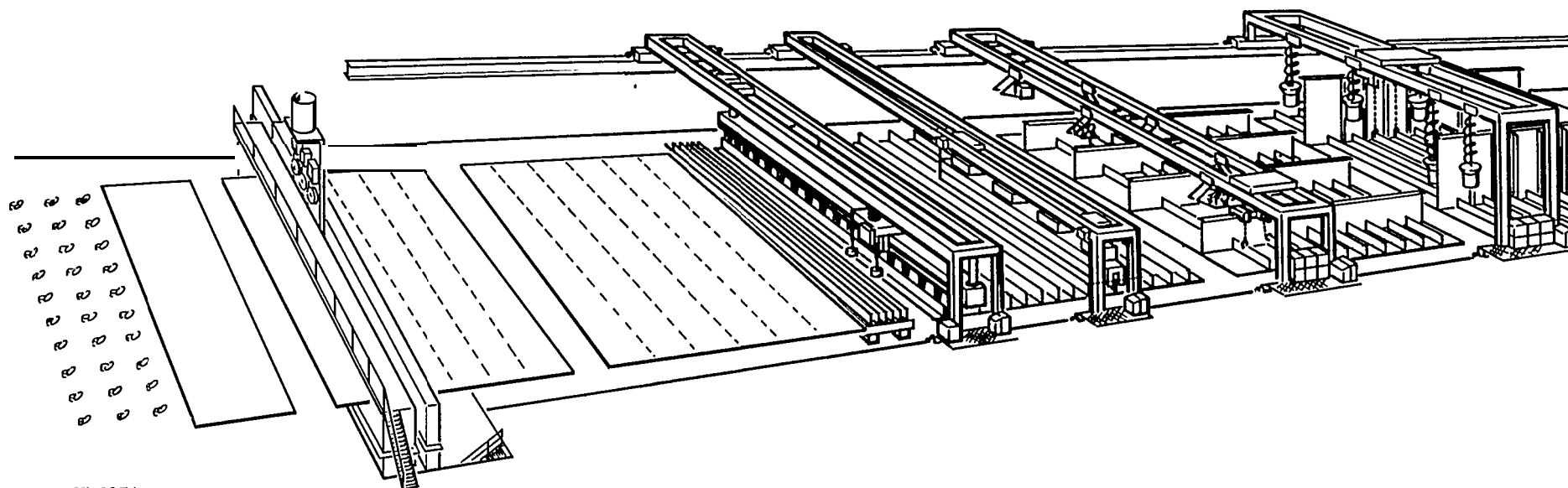
**STIFFENER POSITIONING SYSTEM**, a system which consists of a heavy structural beam and/or gantry, hydraulic, magnetic and/or pneumatic stiffener clamping and positioning equipment and tack welding equipment. Shipyard use is for grasping, clamping and positioning stiffener to plate on a panel line.



T1 2954

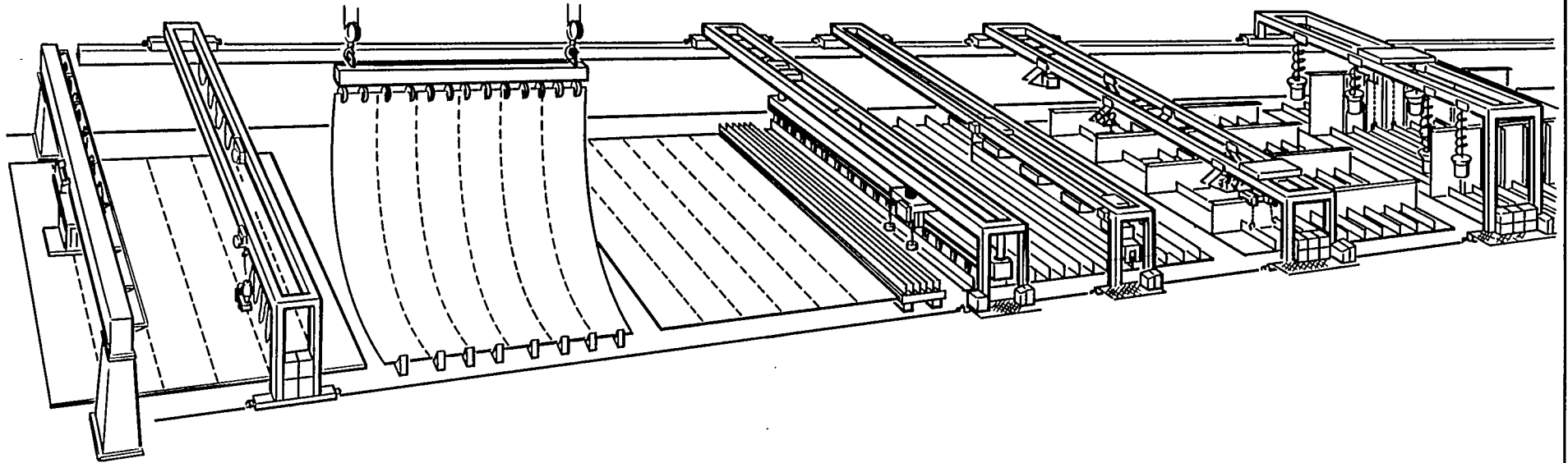


**WEB POSITIONING SYSTEM**, a system which consists of a heavy structural beam and/or gantry, hydraulic, magnetic, pneumatic and/or gear-pulley equipment and tack welding equipment. Shipyard use is for grasping, clamping and positioning longitudinal web frame to plate.



TI 2951

**PANEL LINE WITH ONE-SIDE BUTT WELDING STATION**, stiffener attachment and welding station, web frame attachment and welding station, and bulkhead attachment and final welding station.



TI 2790

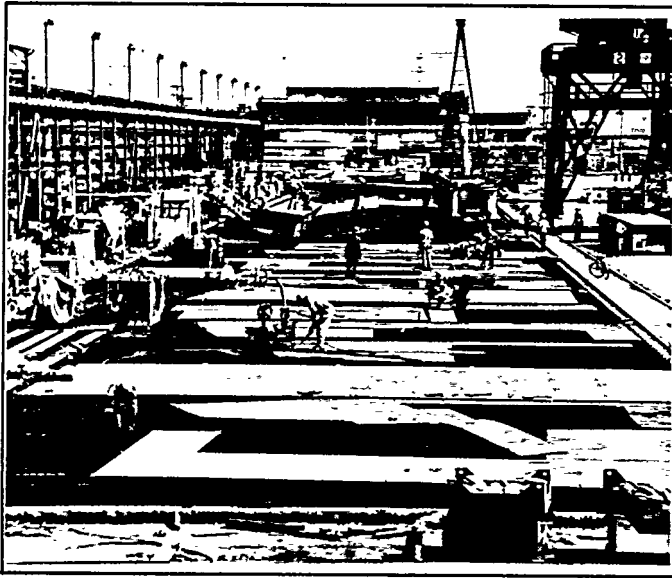
**PANEL LINE WITH TACKING STATION**, two-side butt welding station, stiffener attachment and welding station, web frame attachment and welding station, and bulkhead attachment and final welding station.

## **5.0 APPLICATIONS**

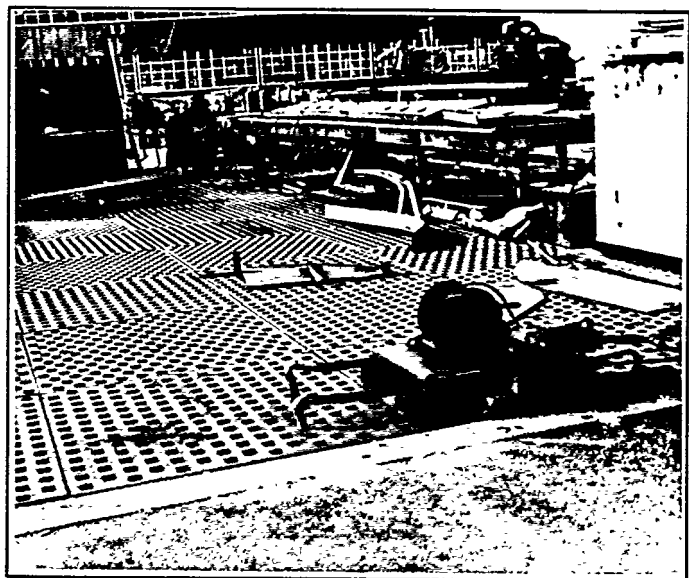
Applications observed during yard visits were too numerous to show; however, a selected group of photographs and illustrations are given. The applications shown have been separated into area and stage of fabrication.

### **5.1 Panel Line**

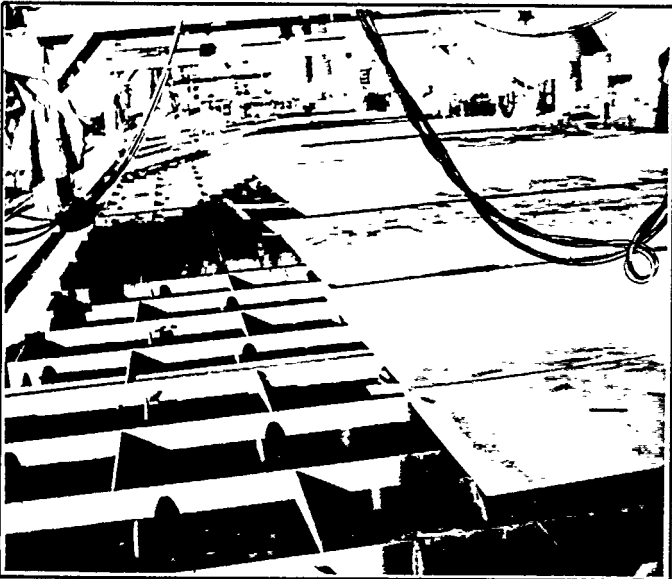
A panel line normally contains a series of fabrication processes and operations to build a fiat subassembly. These operations include the joining of flat deck or bulkhead plate, attachment of longitudinal and transverse stiffeners, and side shell plate and stiffener for placement and joining of the midbody. Usually these operations are performed consecutively and moved automatically through one or more flow lanes. The degree of automation of fitting and fairing aids varies greatly from yard to yard and therefore results in a wide variety of fitting and fairing aids applied at this area and stage.



5.1-1. Conventional platen



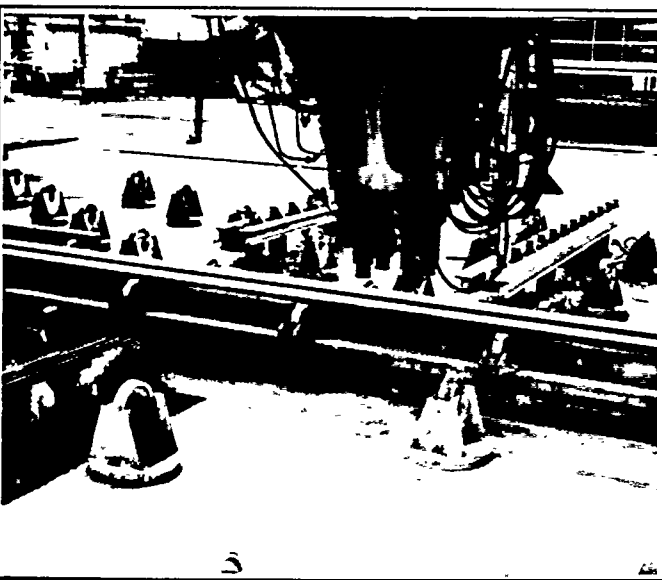
5.1-2. Conventional pin slab platen



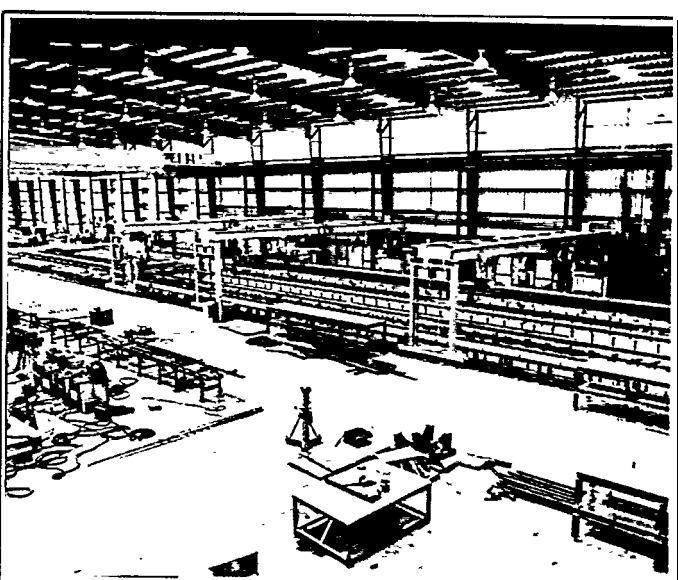
5.1-3. Panel line with rollers



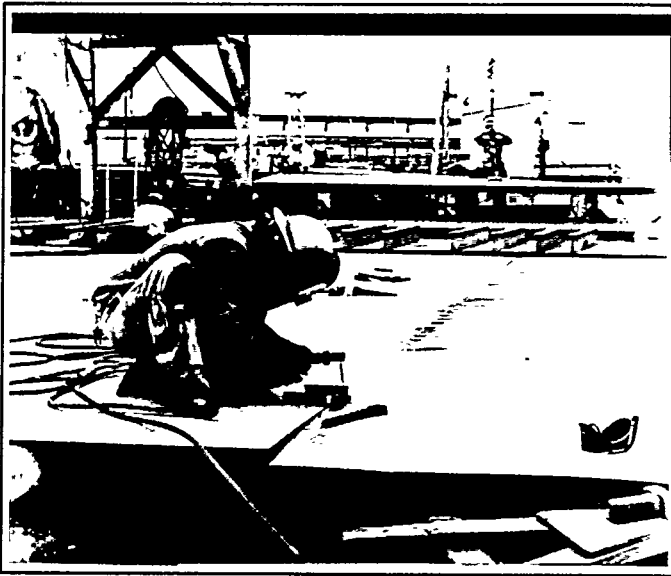
5.1-4. Panel line with rollers



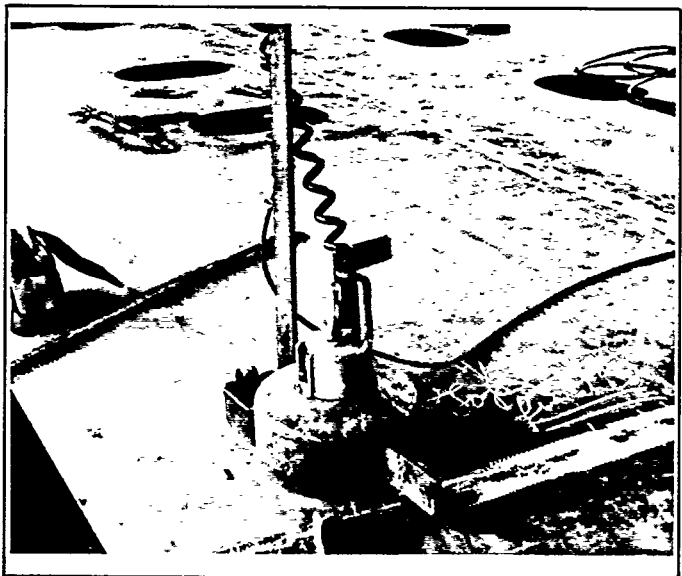
5.1-5. Panel line with rollers



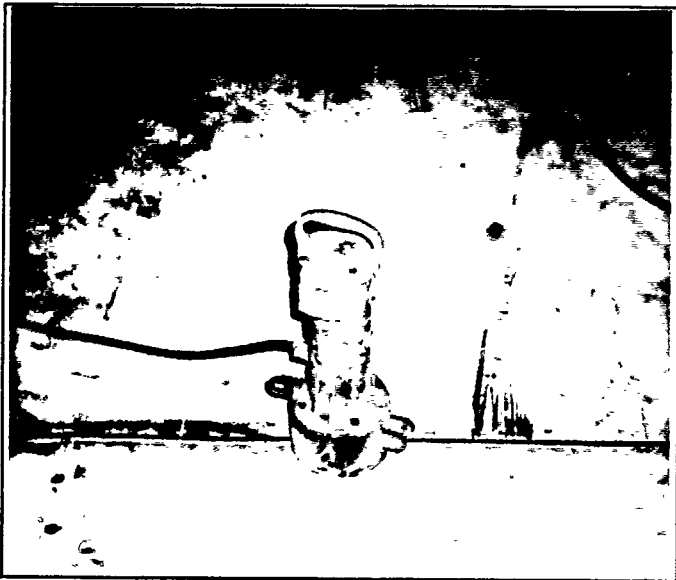
5.1-6. Mechanized panel line



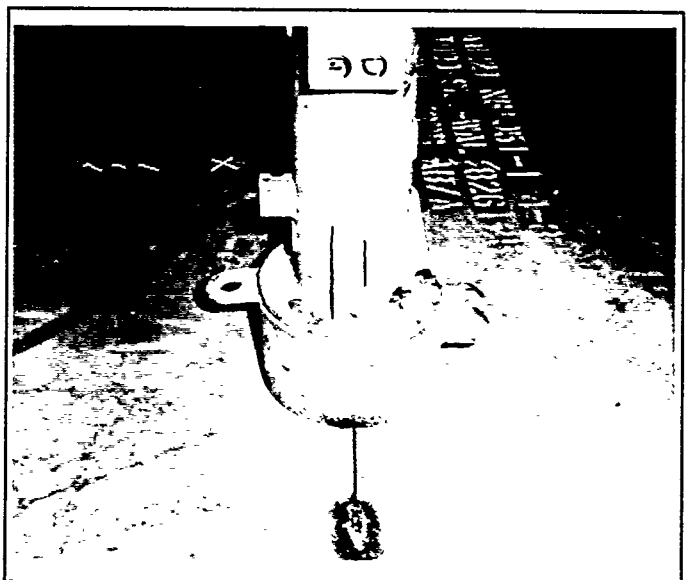
5.1a-1. Fairing with a dog and wedge



5.1a-2. Fairing with a magnet



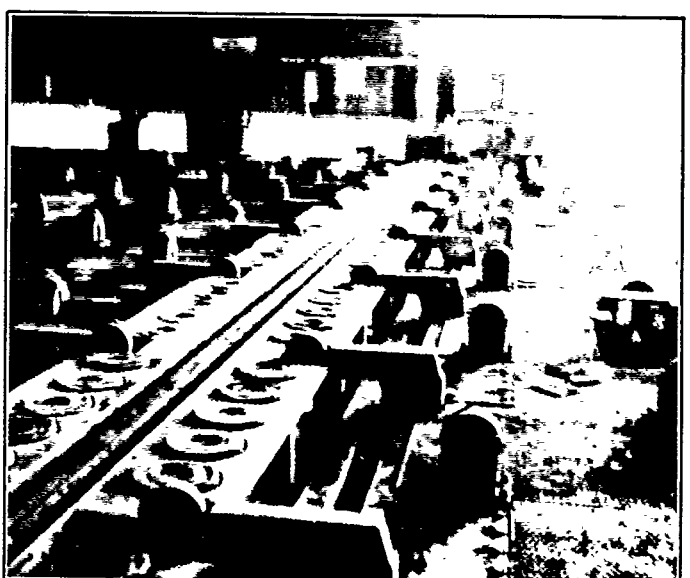
5.1a-3. Fairing with a magnet



5.1a-4. Fairing with a magnet



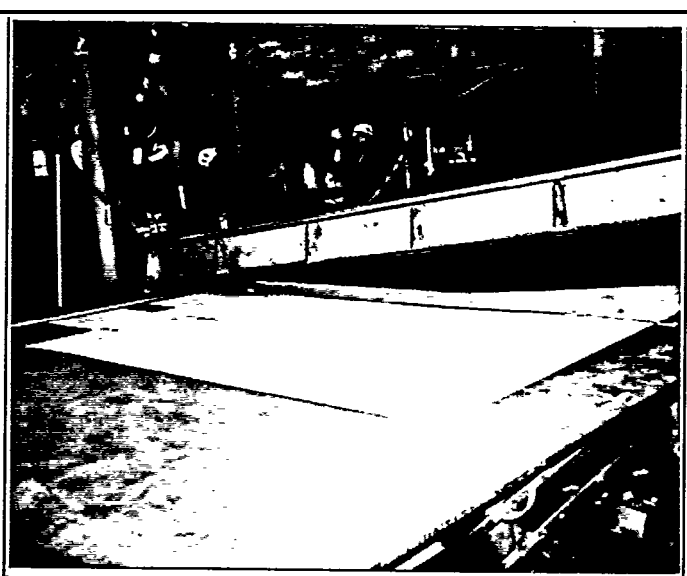
5.1a-5. Fairing with a magnet



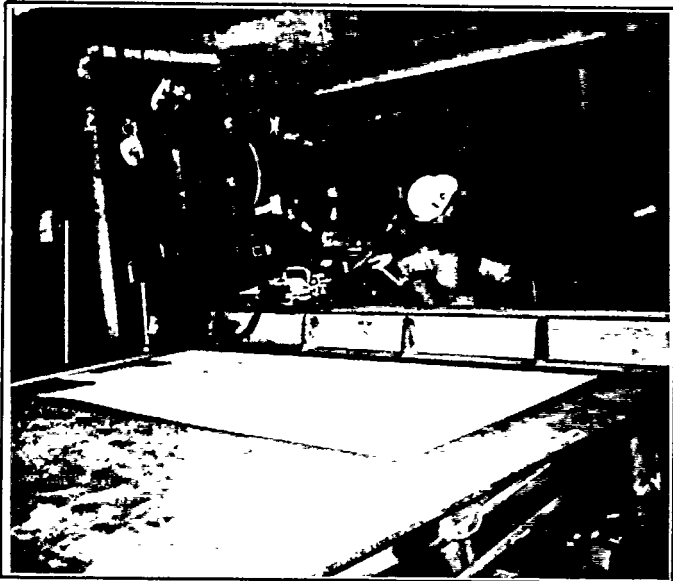
5.1a-6. Magnetic holddown bed



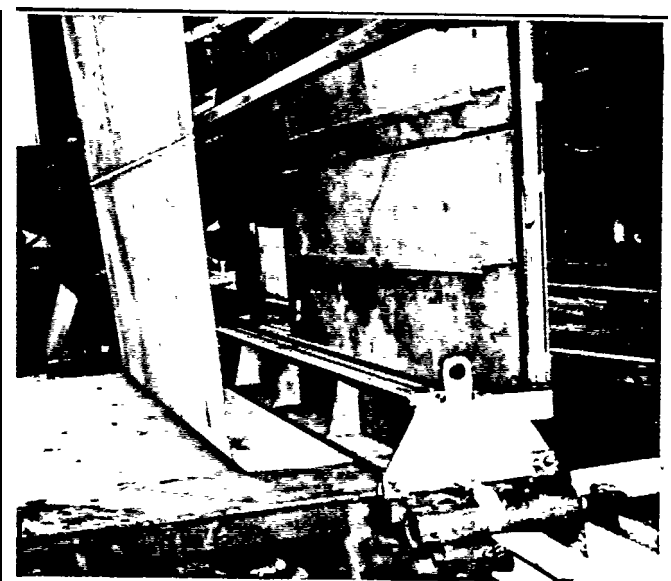
5.1a-7. Fairing with hydraulic rams



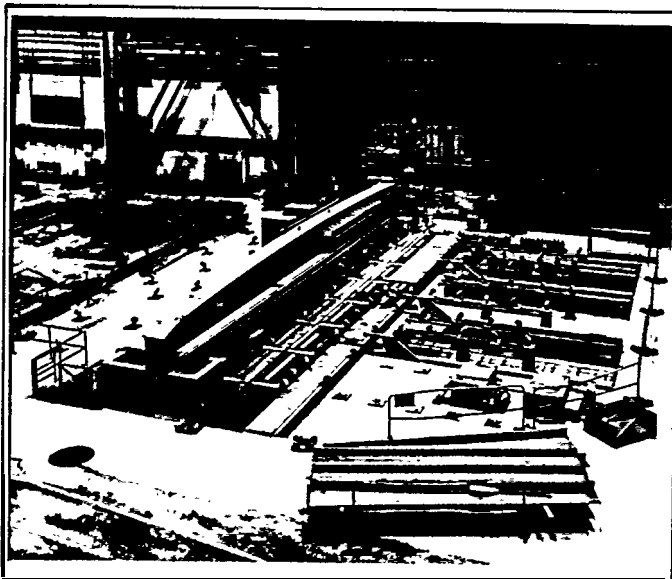
5.1a-8. One side welding with hydraulic restraint



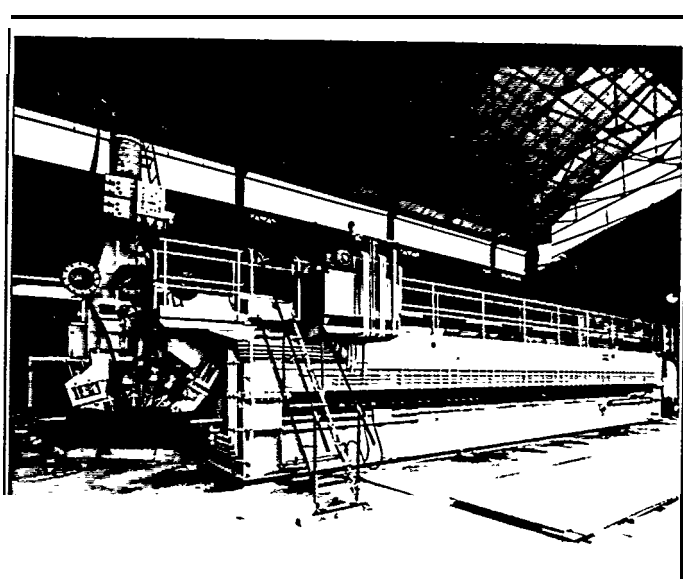
5 a 9 O w g w



5.1a-10. One side welding with hydraulic restraint

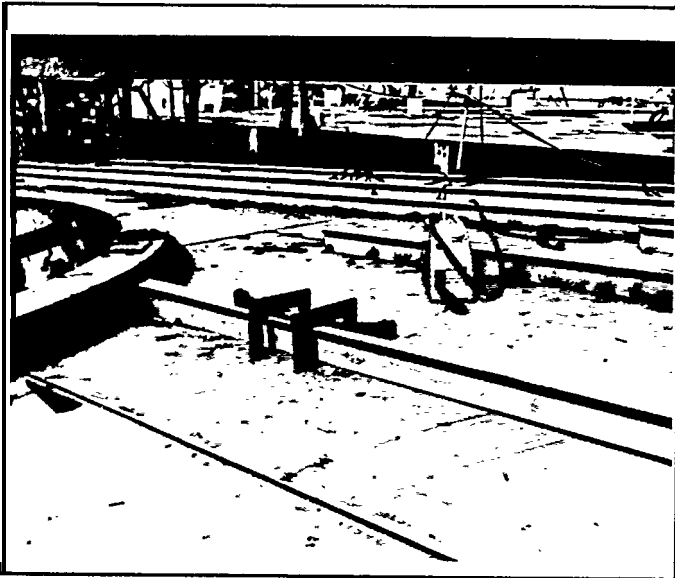


5.1a-11. One side welding with magnetic holddown bed

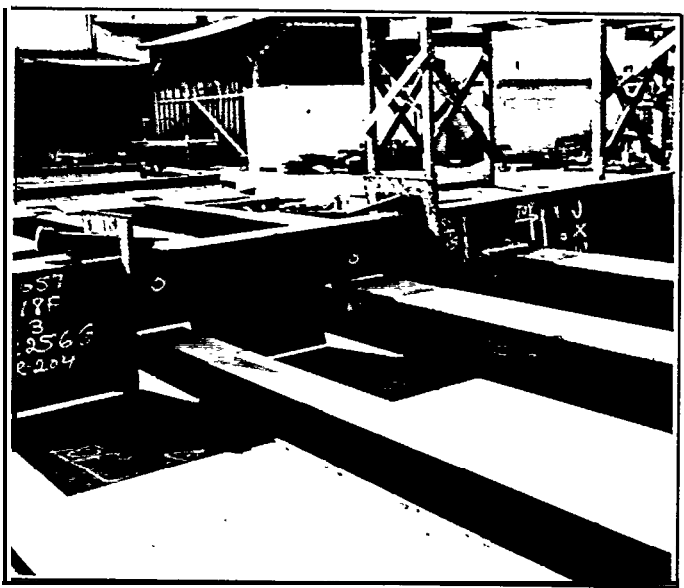


5.1a-12. One side welding with hydraulic holddown ram

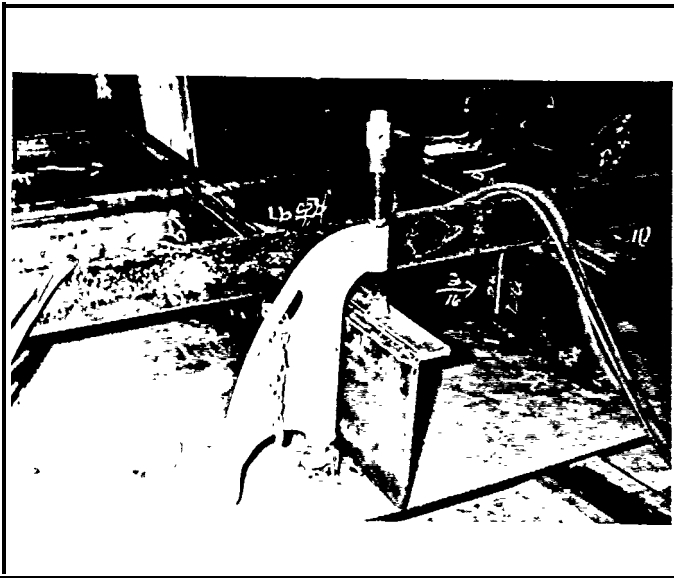




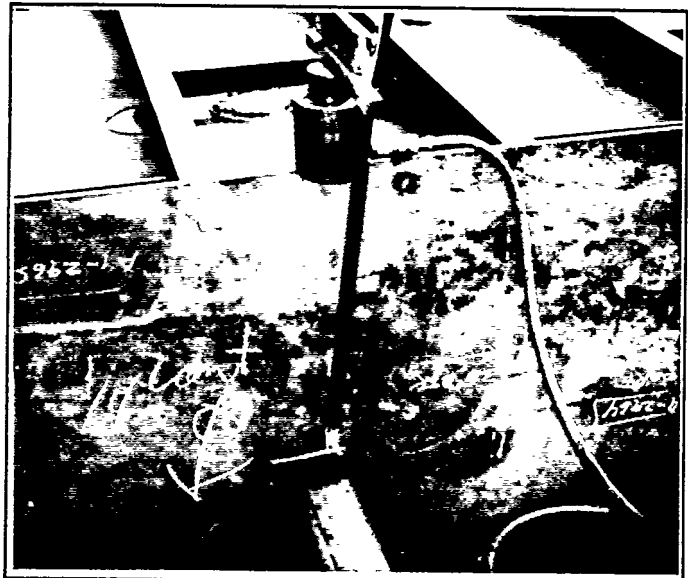
5.1b-1. Stiffener attachment with saddle and wedge



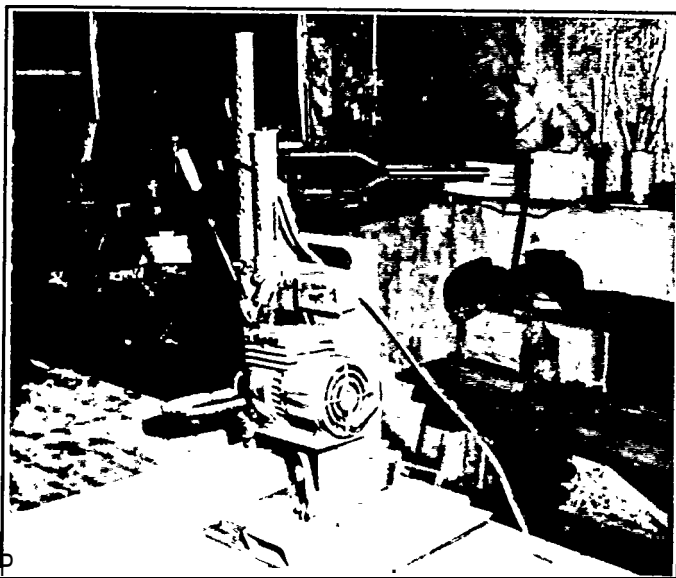
5.1 b-2. Web frame attachment with saddle and wedge



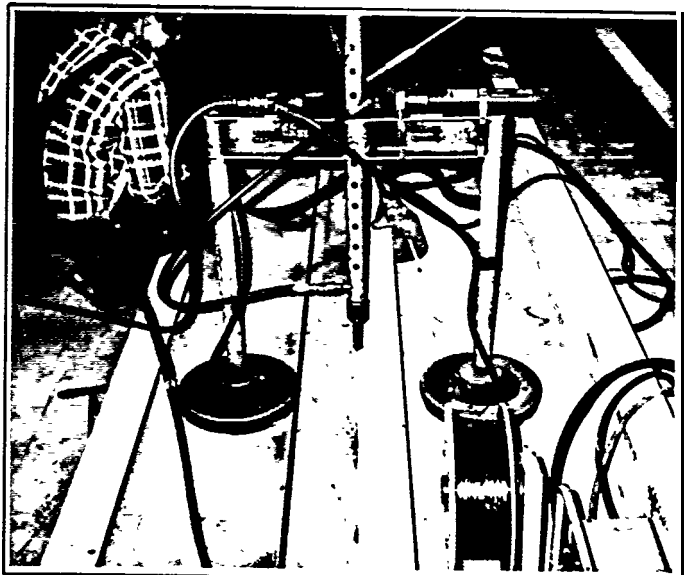
5.1b-3. Stiffener attachment with jacking clamp



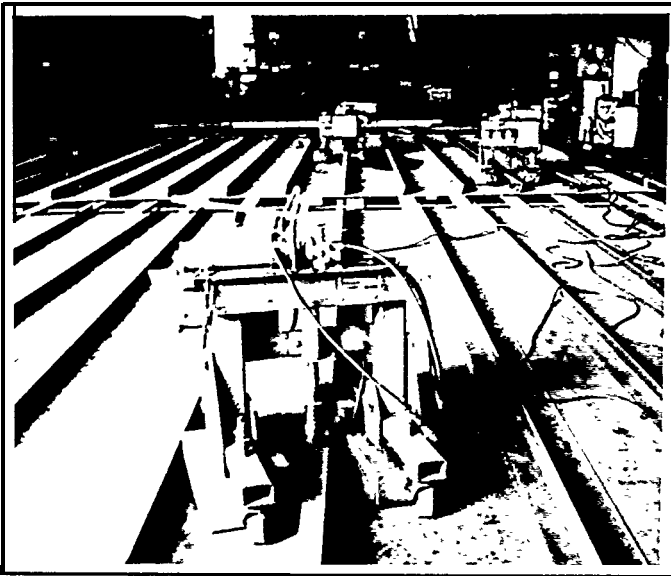
5.1 b-4. Hydraulic cylinder and reusable saddle



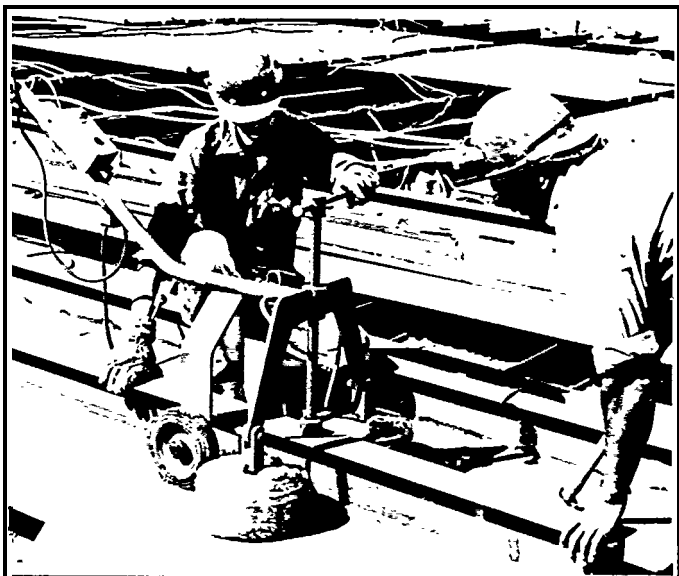
5.1 b-5. Aluminum stiffener attachment with vacuum clamp



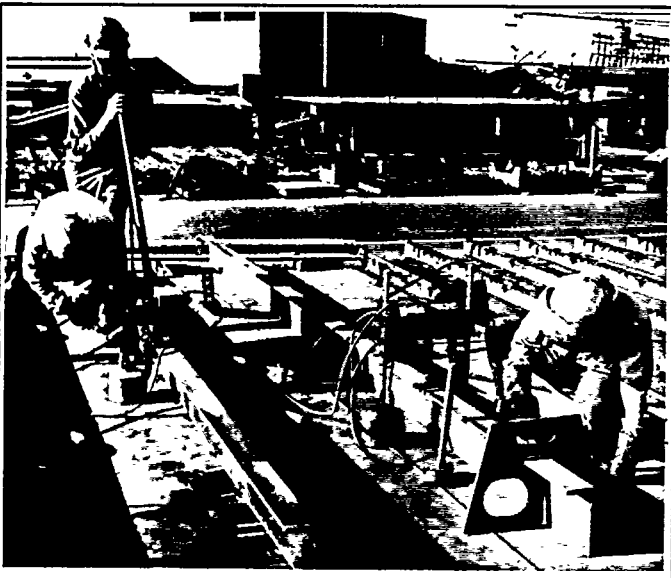
5.1 b-6. Stiffener attachment with a vacuum saddle



5.1 b-7. Stiffener attachment with magnetic saddle



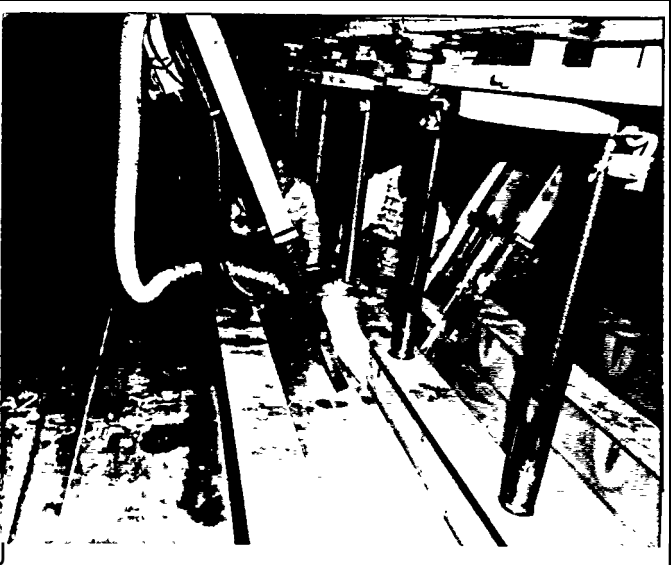
5.1b-8. Stiffener attachment with magnetic saddle



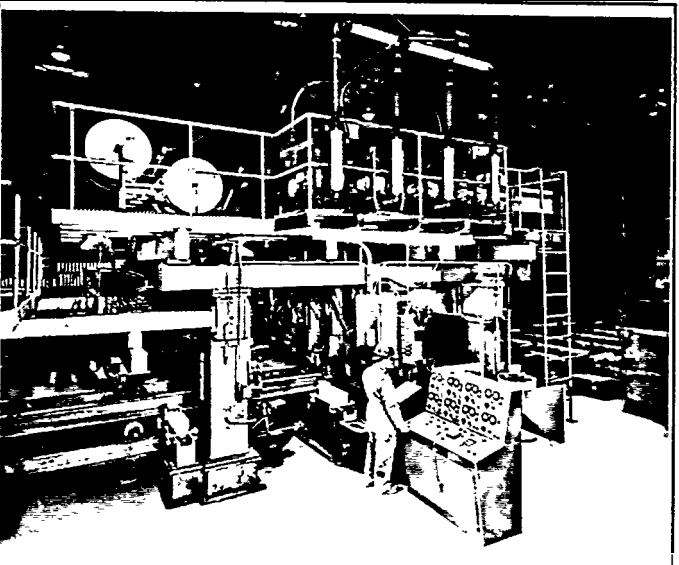
5.1b-9. Stiffener attachment with magnetic saddle



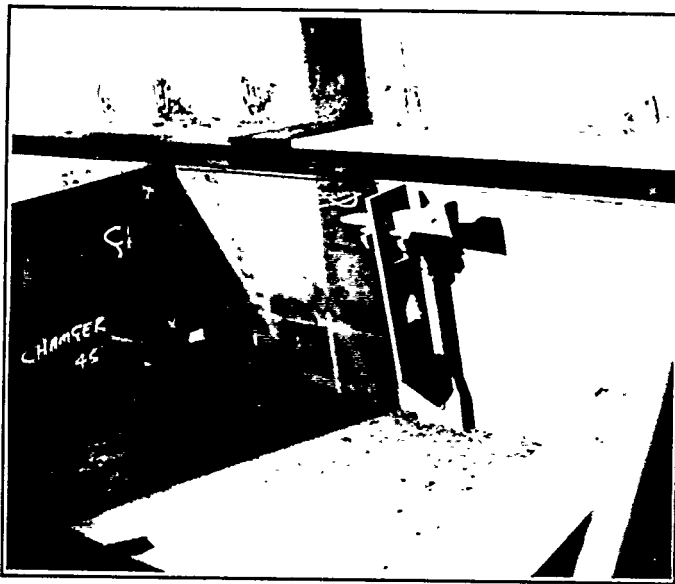
5.1b-10. Magnetic placement hydraulic holddown



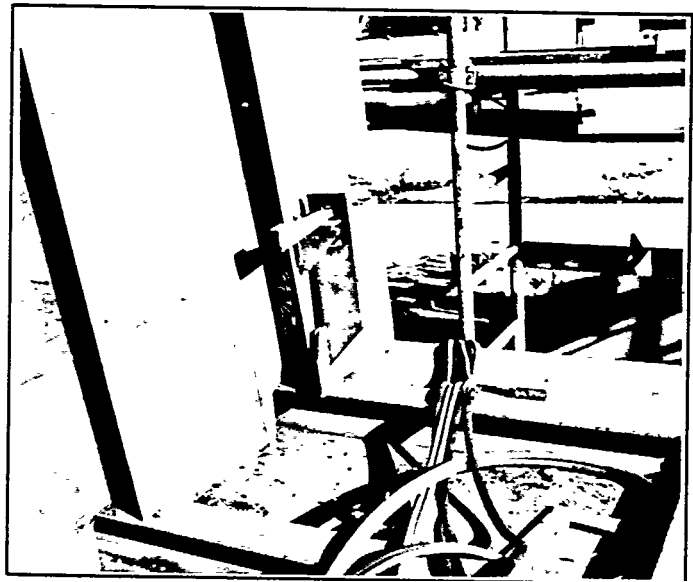
5.1 b-1 1. Hydraulic holddown rams



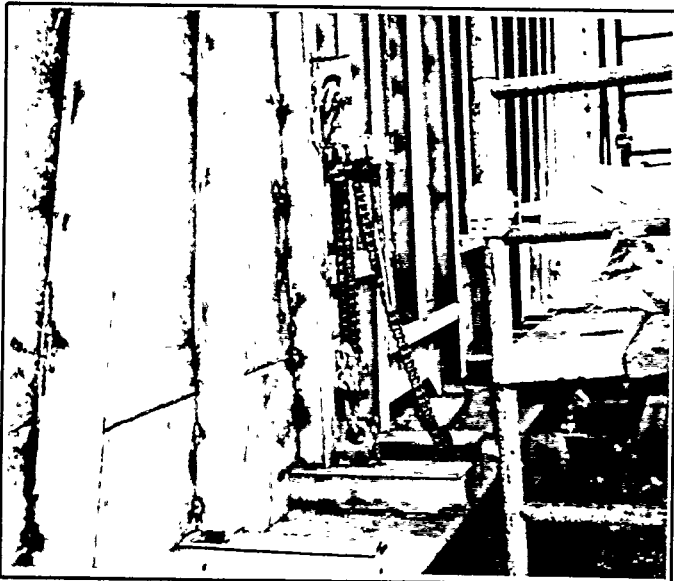
5.1b-12. Four stiffeners automatically fit and welded



5.1c-1. Pull down used on bulkhead



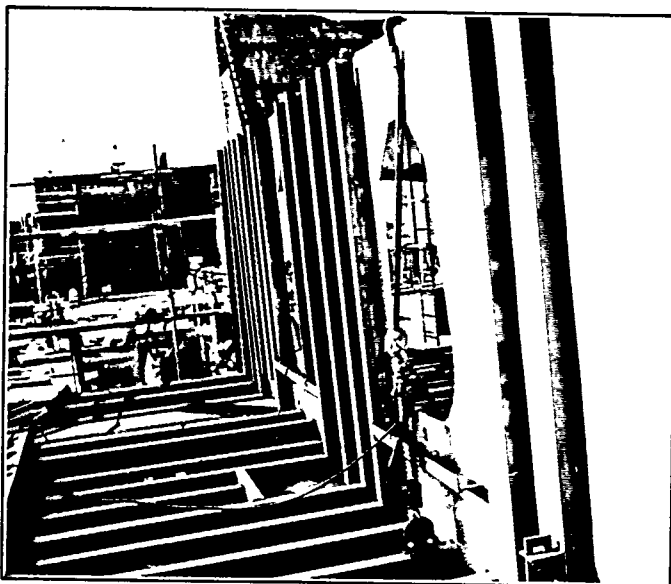
5.1 c-2. Pull down used on bulkhead



5.1c-3. Welded padeye and come-along to pull down bulkhead



5.1 c-4. Push-pull jack used to align bulkhead



5.1 c-5. Come-along and reusable attachments used to pull down bulkhead



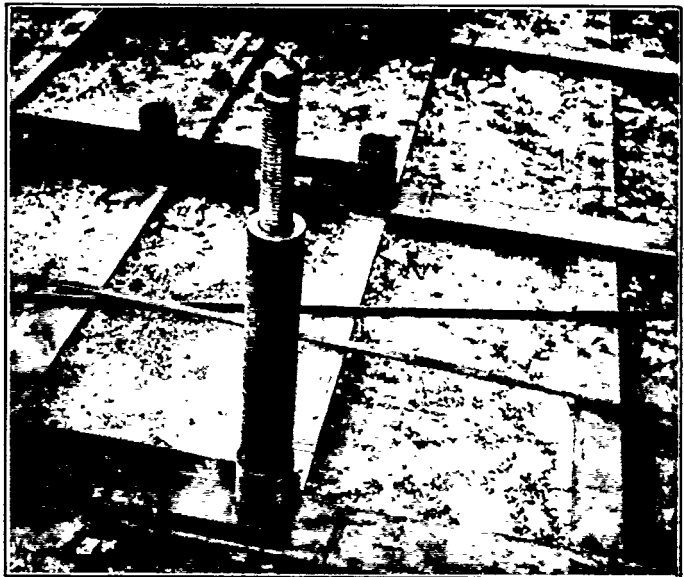
5.1 c-6. Come-along and reusable attachments used to pull down bulkhead

## **5.2 Subassemblies and Foundations**

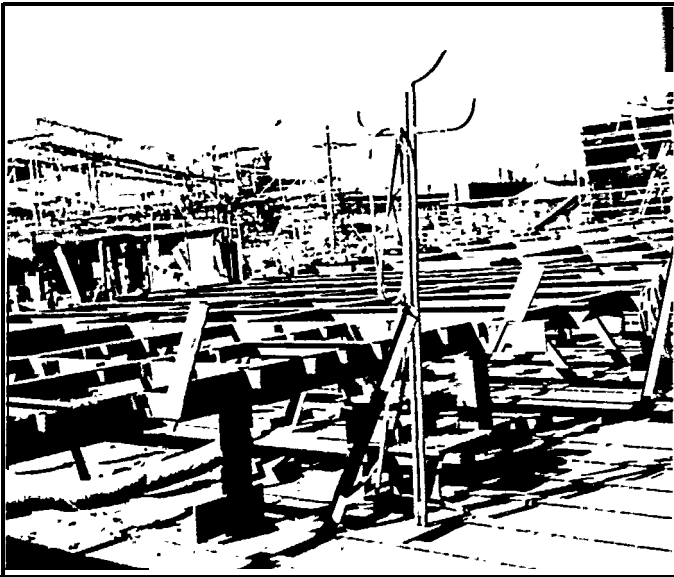
Subassembly and foundation fabrication is often broken down into further classifications: fiat, simple curved, complex curved, parallel and nonparallel, and by size and weight. Subassemblies are structural portions of the ship which form units or blocks when joined together. Foundations are supporting structures for machinery and equipment. Many subassemblies and foundations are made on jigs, mocks and fixtures used as fitting aids to maintain alignment. There are many types of jigs, mocks and fixtures and fitting and fairing aids used in conjunction with them. Subassembly and foundation fabrication is also done on platens and pin tables with which fitting and faking aids are also employed in wide variation. Since there are no hard and fast rules in the fabrication of these types of components, shipyards are using an abundance of different methods, techniques and devices on similar applications.



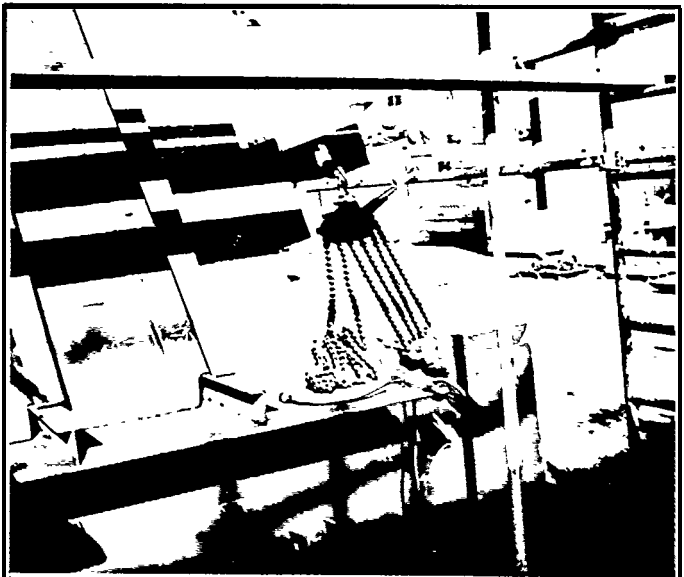
5.2a-1. Pin jig



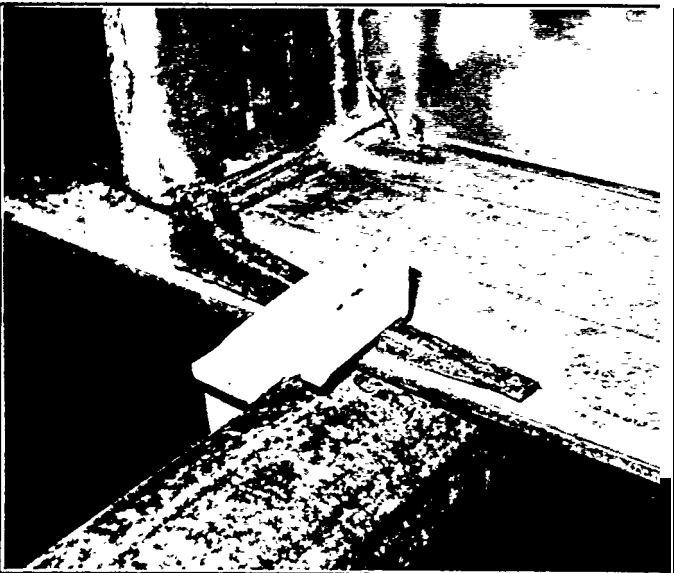
5.2a-2. Pin from pin jig



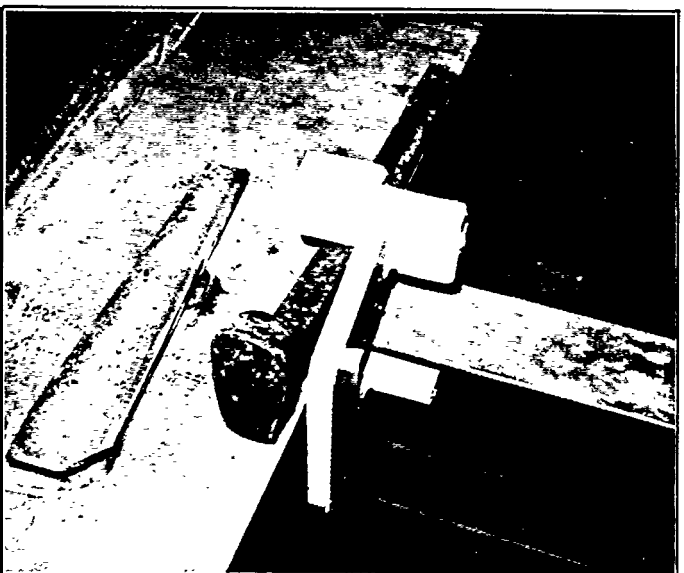
5.2a-3. Rigid mock



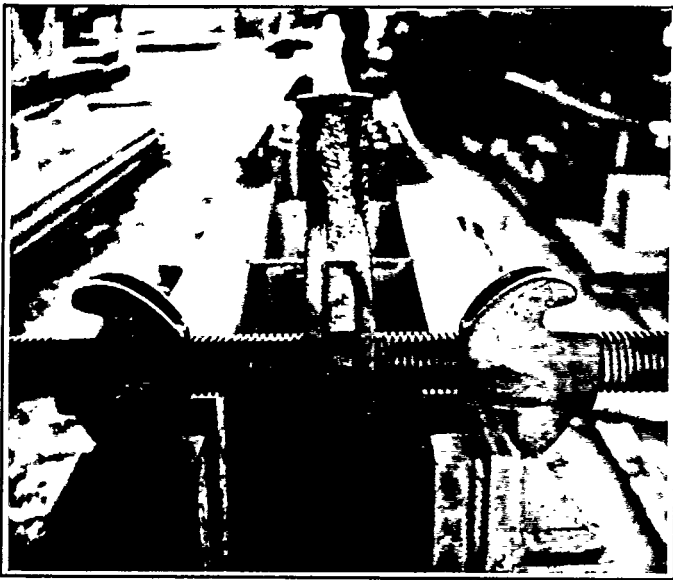
5.2b-1. Come-along used to hold assembly to mock



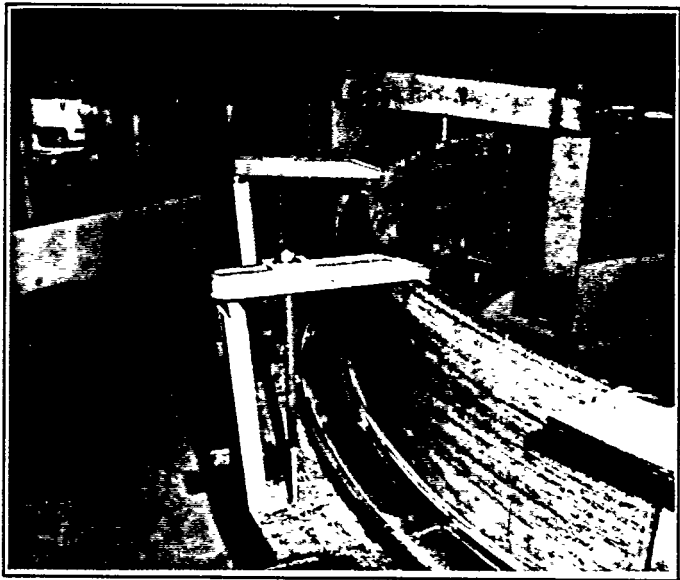
5.2b-2. Assembly secured by reusable aid



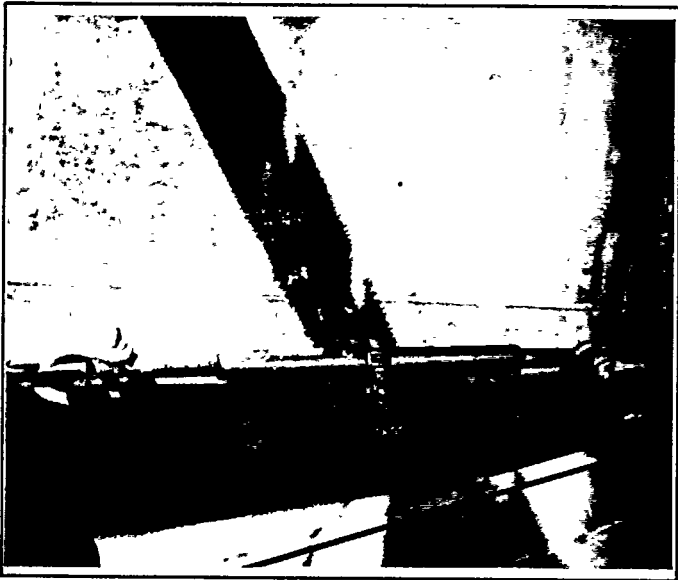
5.2b-3. Assembly secured by reusable aid



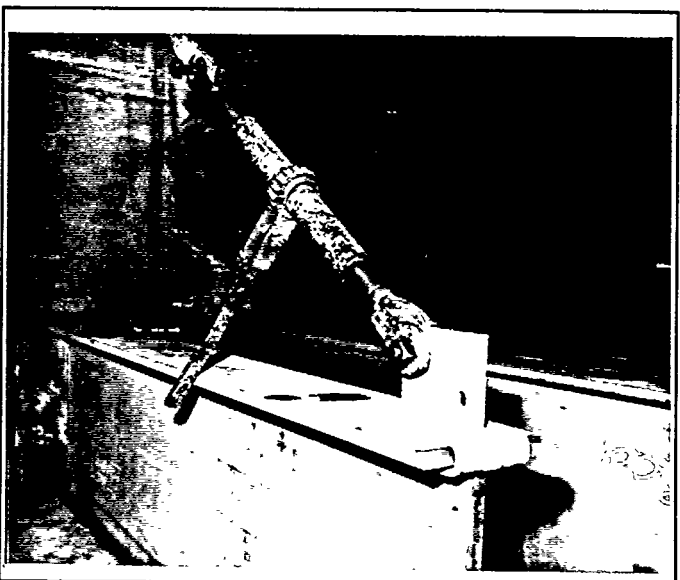
5.2c-1. Push-pull jack used to bring parts together



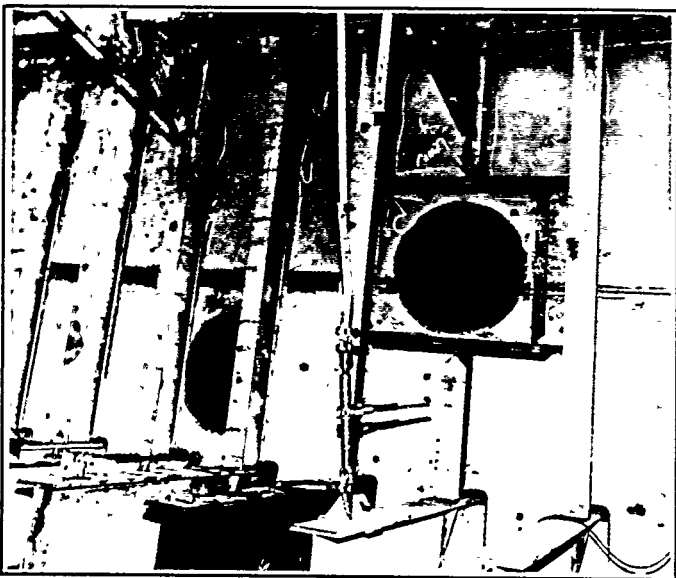
5.2c-2. Threaded device used to fit parts together



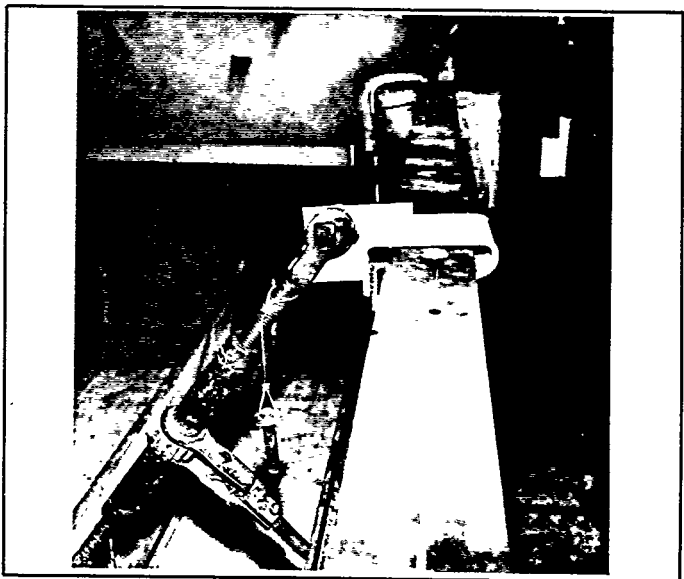
5.2c-3. Push-pull jack used to pull parts together



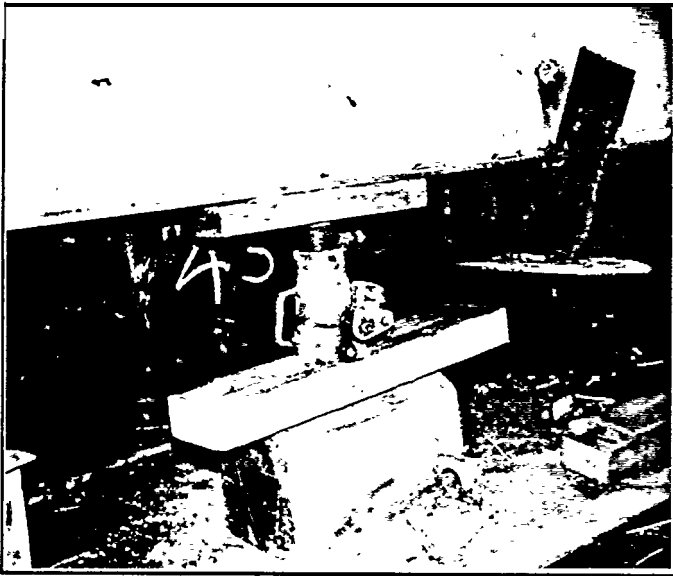
5.2c-4. Push-pull jack and clip used to align parts



5.2c-5. Push-pull jack used to pull down a part



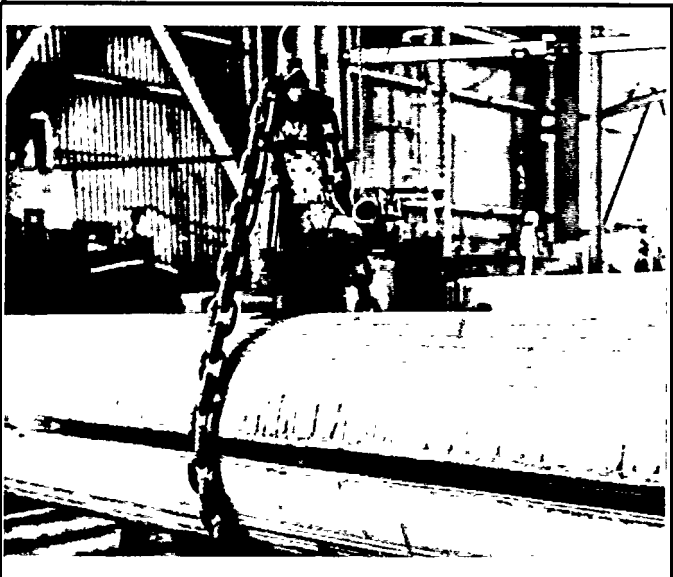
5.2c-6. Push-pull jack used to align parts



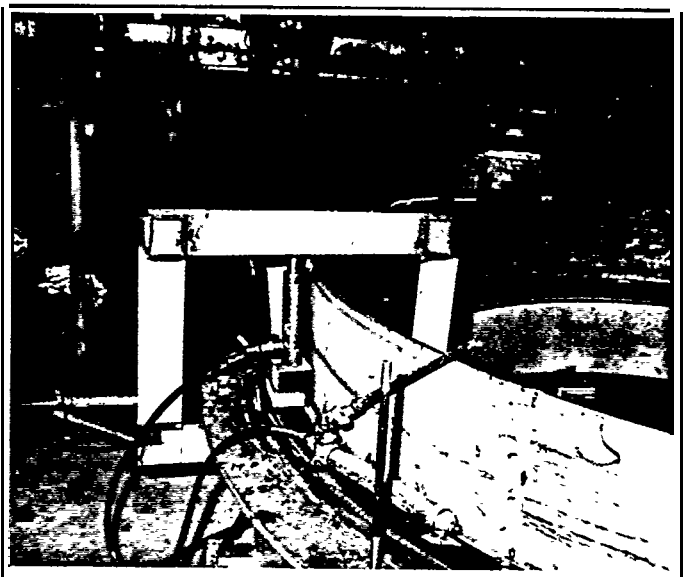
5.2c-7. Jack used to lift unit



5.2c-8. Jack used to lift bulkhead



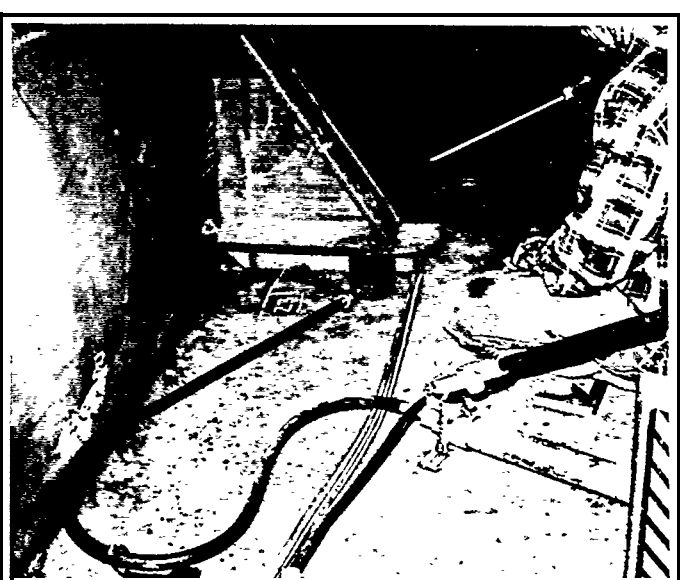
5.2c-9. Jack and chain saddle used to bring parts together



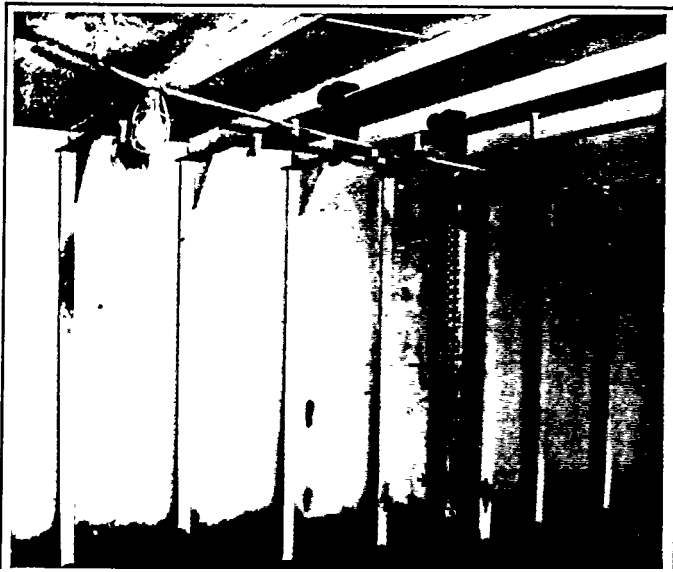
5.2c-10. Hydraulic cylinder and reusable saddle used to restrain part



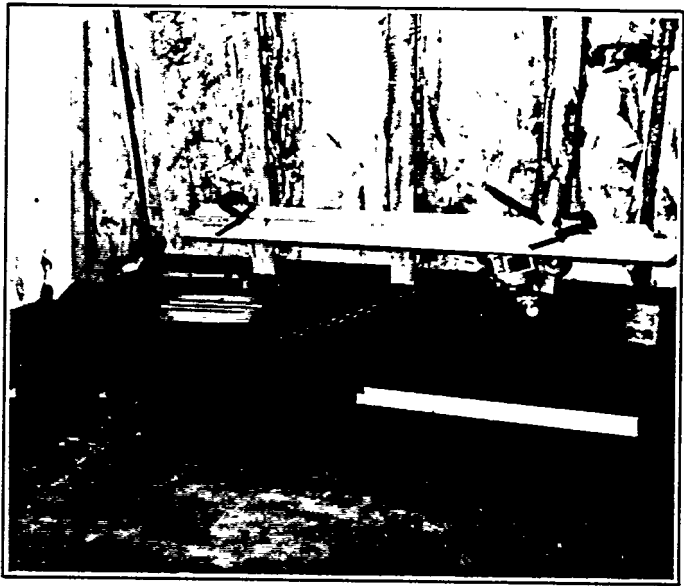
5.2c-11. Hydraulic cylinder and portable stanchion used to move deck



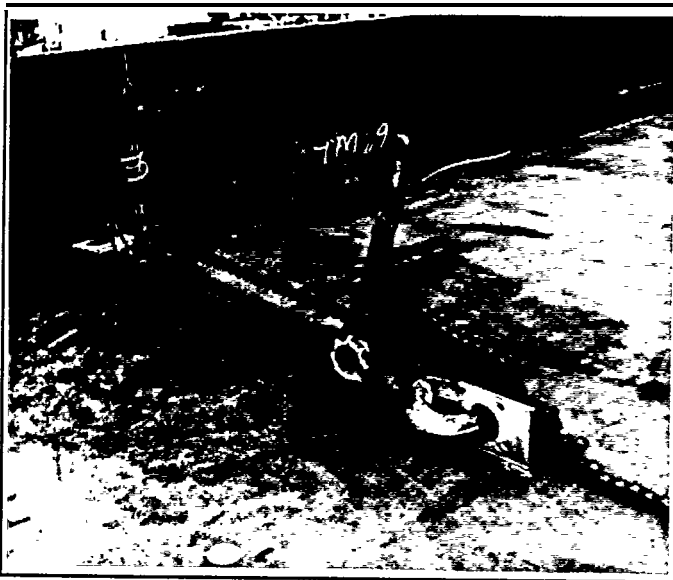
5.2c-12. Hydraulic cylinder used to move bulkhead



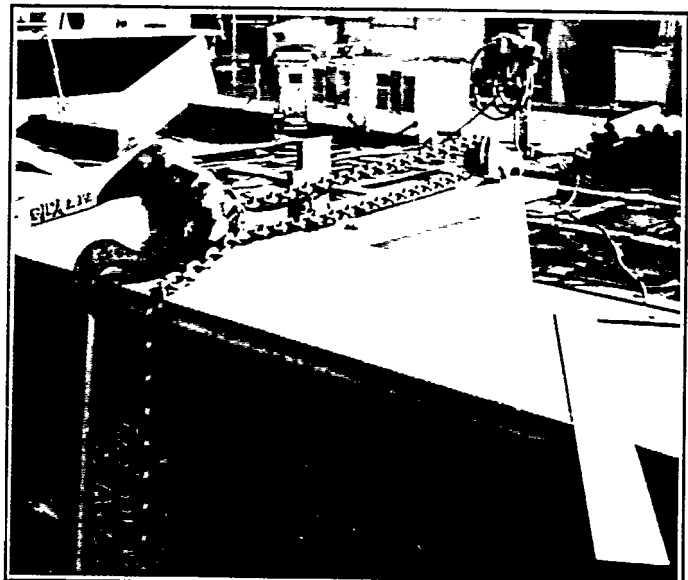
5.2c-13. Come-along used to pull unit down



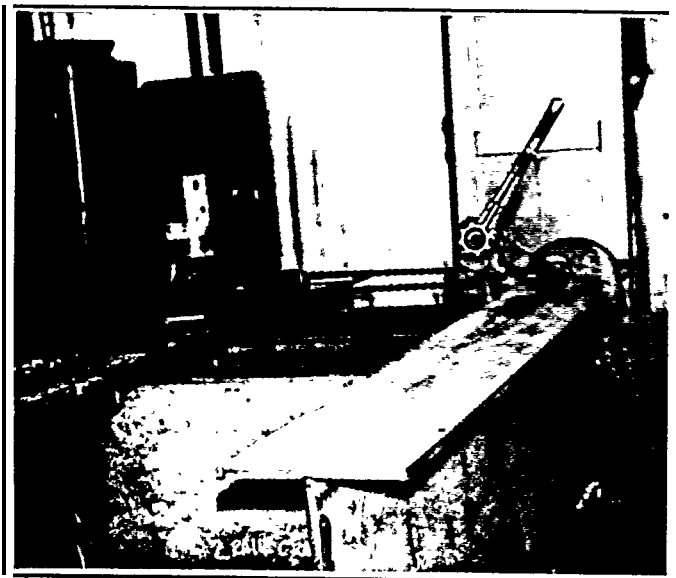
5.2c-14. Come-along used to move unit



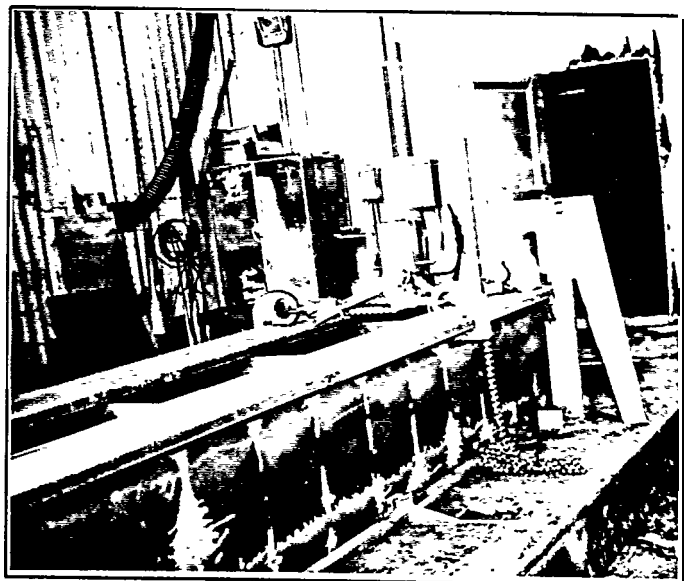
5.2c-15. Come-along used to pull parrs together



5.2c-16. Come-along used to pull parts together

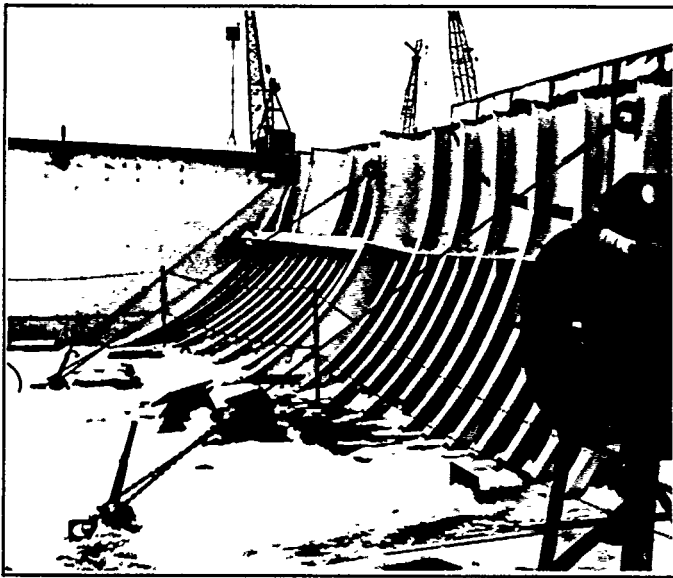


5.2c-17. Come-along used to pull parts together

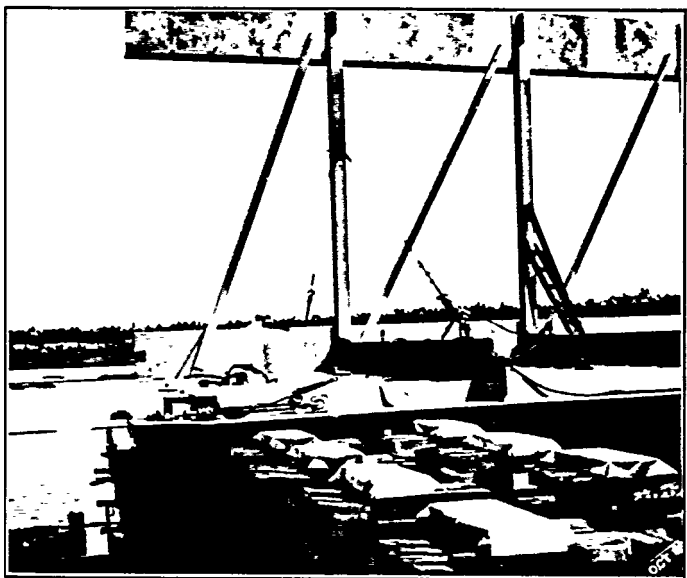


5.2c-18. Come-along used to pull parts together





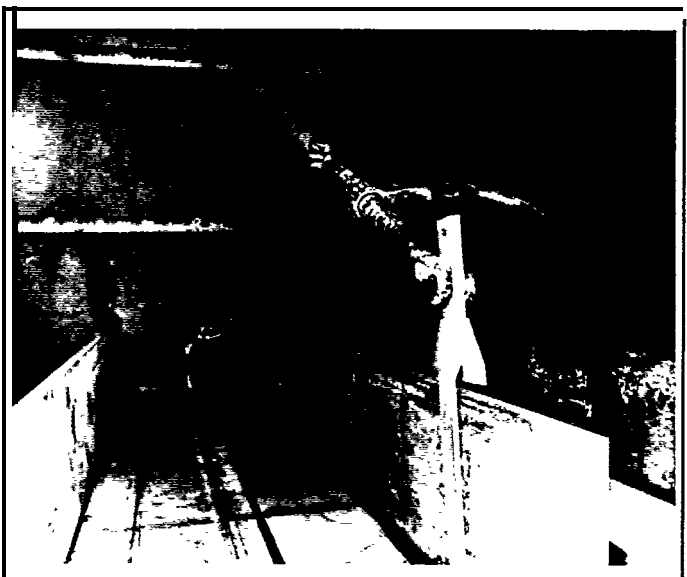
**5.2c-19.** Come-along used to support side shell



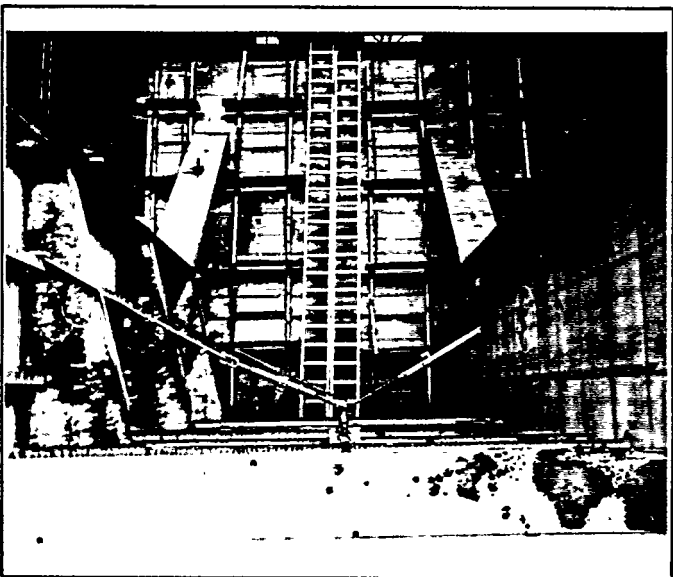
**5.2c-20.** Come-along used to support subassembly



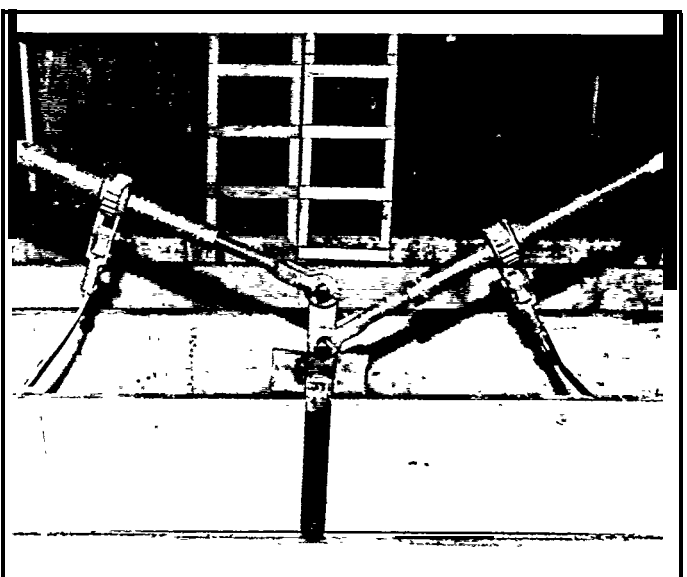
**5.2c-21.** Turnbuckle used to align and support bulkhead



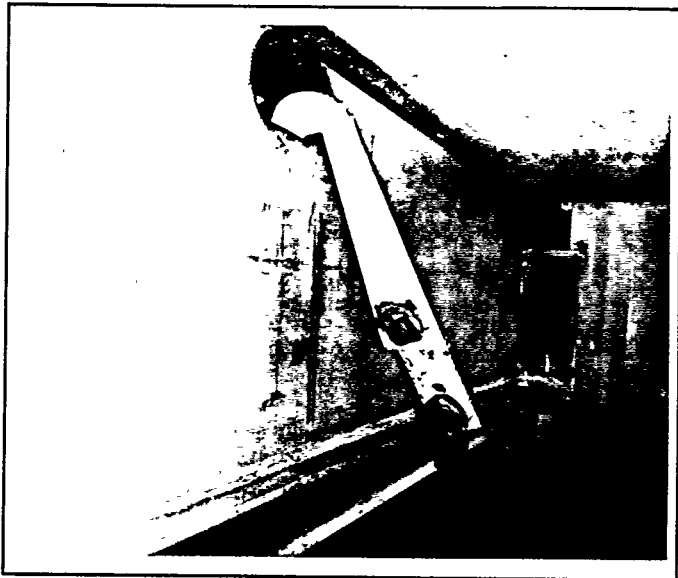
**5.2c-22.** Push-pull jack use to support assembly members



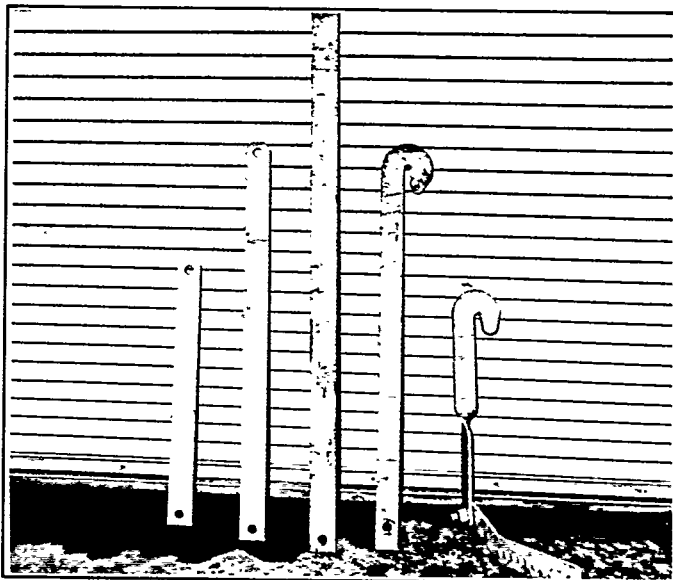
**5.2c-23.** Push-pull jack used to support assembly members



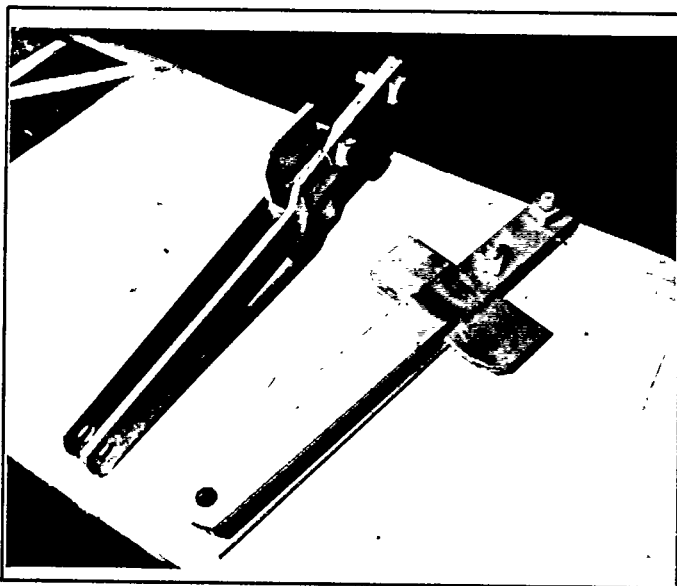
**5.2c-24.** Connector for push-pull jacks



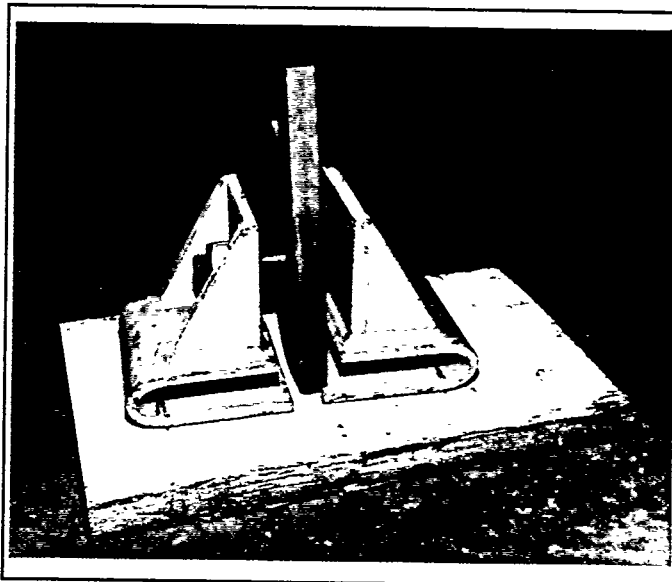
5.2c-25. End attachment



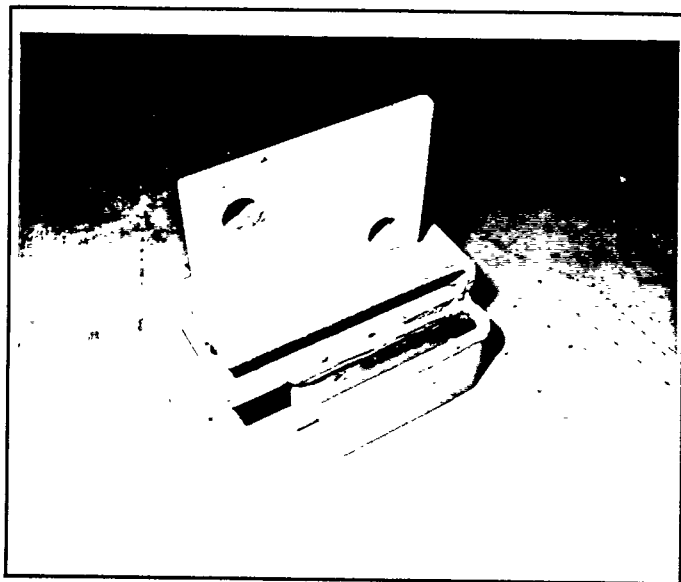
5.2c-26. Assorted connectors and end attachments



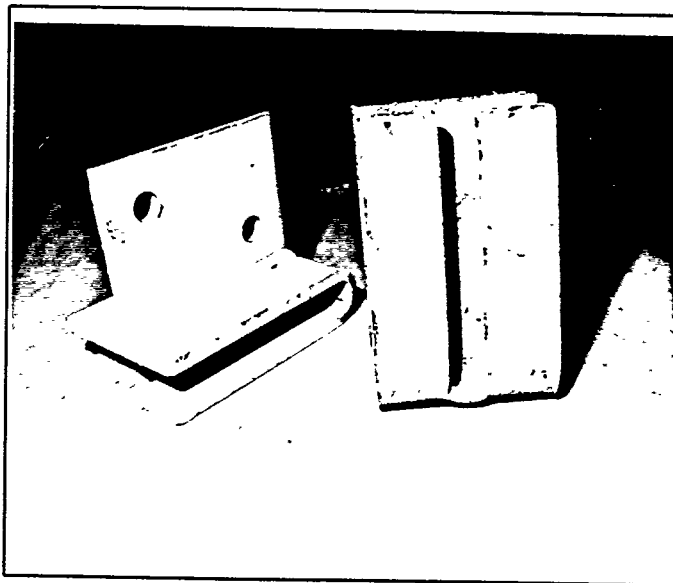
5.2c-27. Connector and attachment combination



5.2c-28. Beam clamp



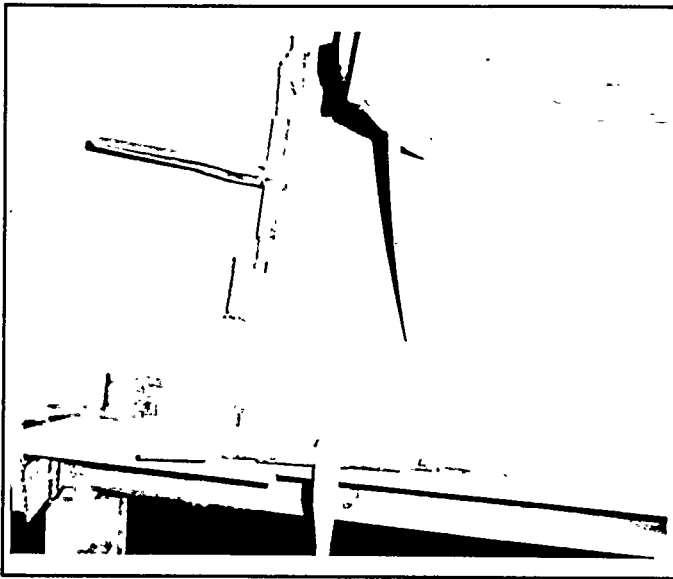
5.2c-29. Connector and attachment combination



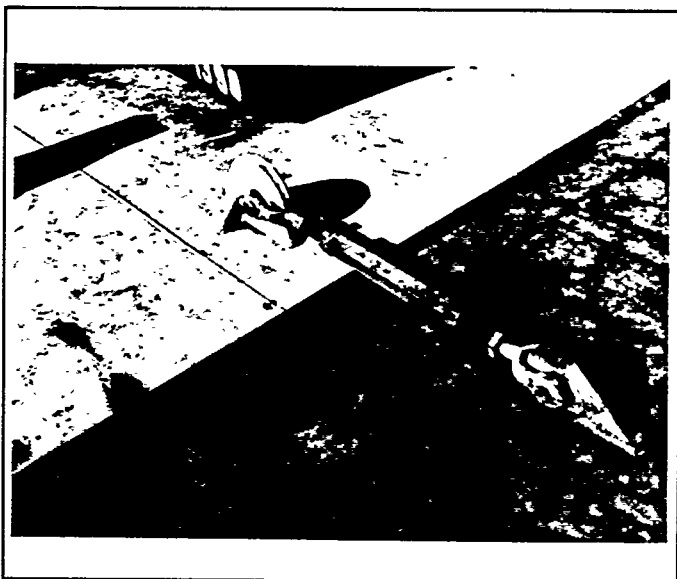
5.2c-30. Connector and attachment combination

### **5.3 Erection**

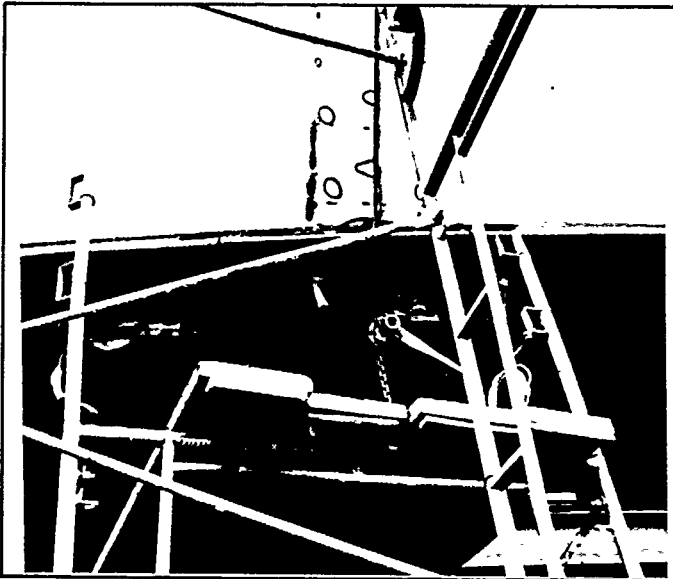
The erection stage of fabrication involves the alignment and joining of units or blocks into the complete ship structure. The fitting at this stage is very complex and involves aligning the hull, transverse and longitudinal stiffeners, decks, bulkheads, frames, beams and piping. Fitting and fairing at this stage is accomplished with portable devices which can be transported to the erection site and handled easily.



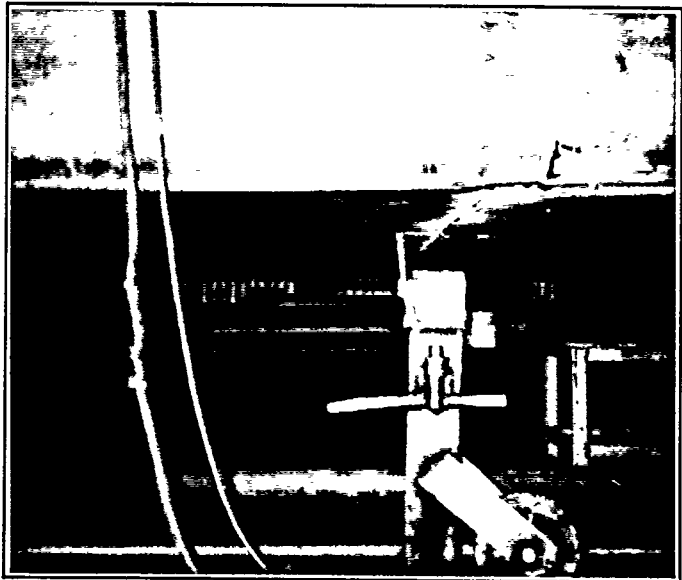
5.3a-1. Push-pull jack used to pull unit together



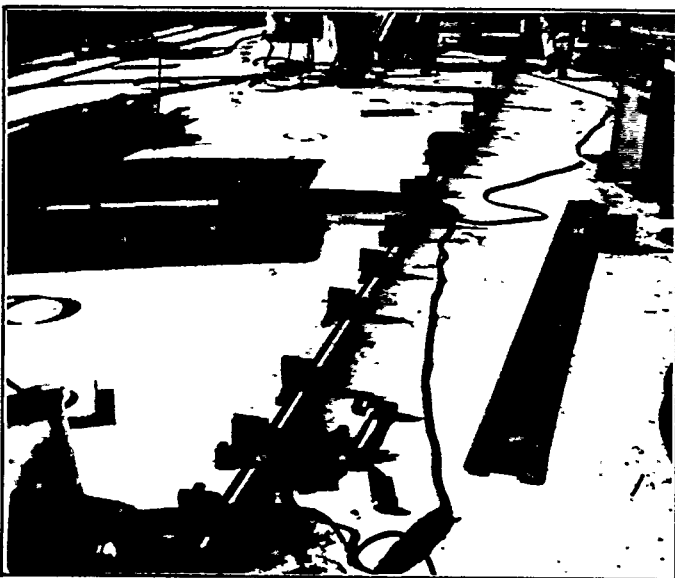
5.3a-2. Turnbuckle used to pull units together



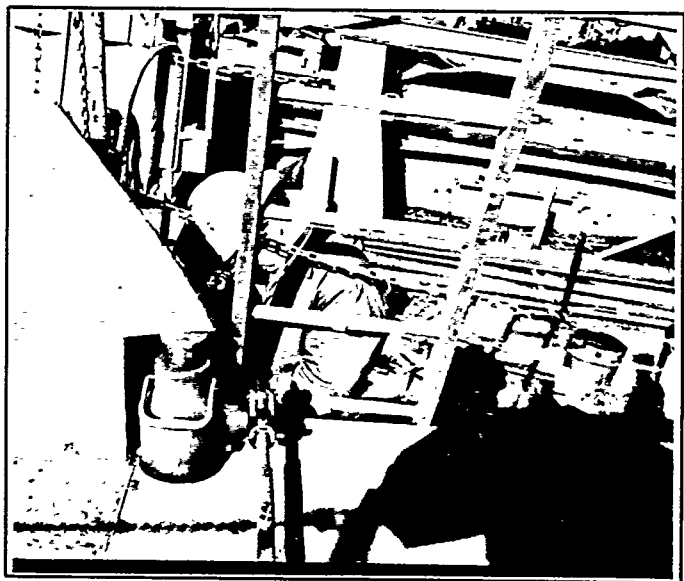
5.3a-3. Come-along used to pull units together



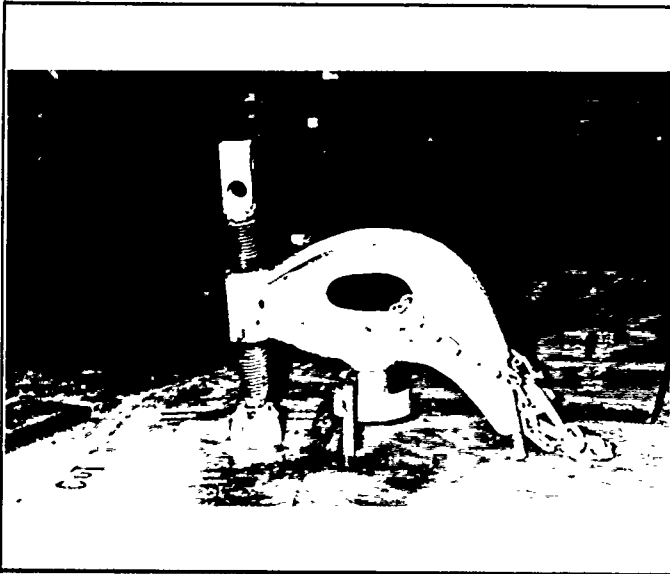
5.3a-4. Hydraulic jack stand used to push unit from battery



5.3a-5. Dog and wedge used to align deck seam



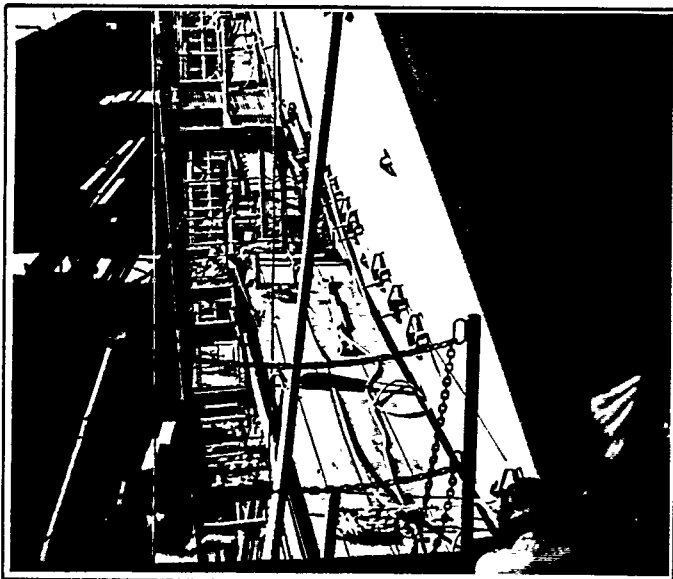
5.3a-6. Jack and oversize dog used to align deck seam



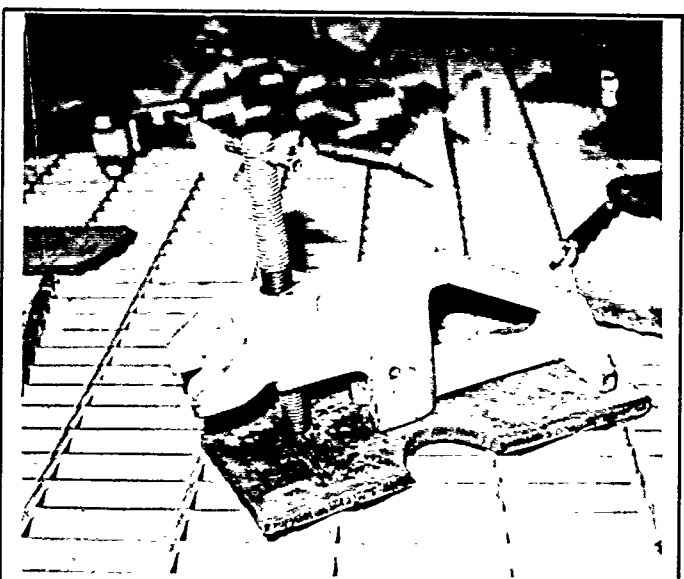
5.3a-7. Small jacking clamp used to align plating



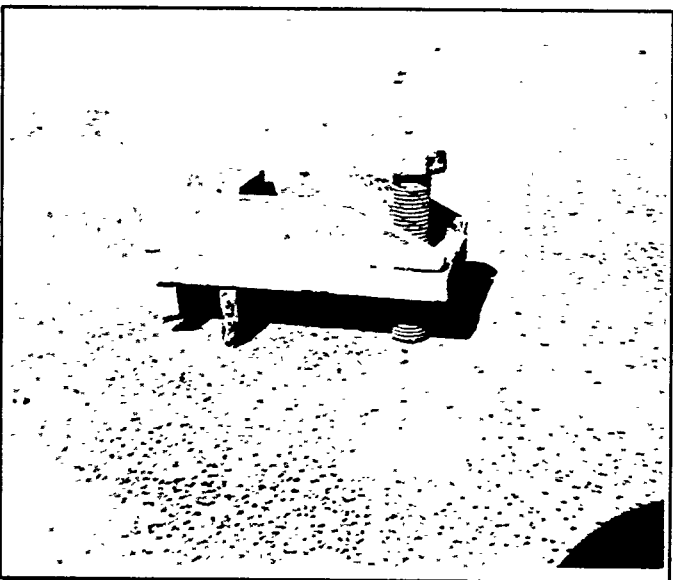
5.3a-8. Large jacking clamps used to align plating



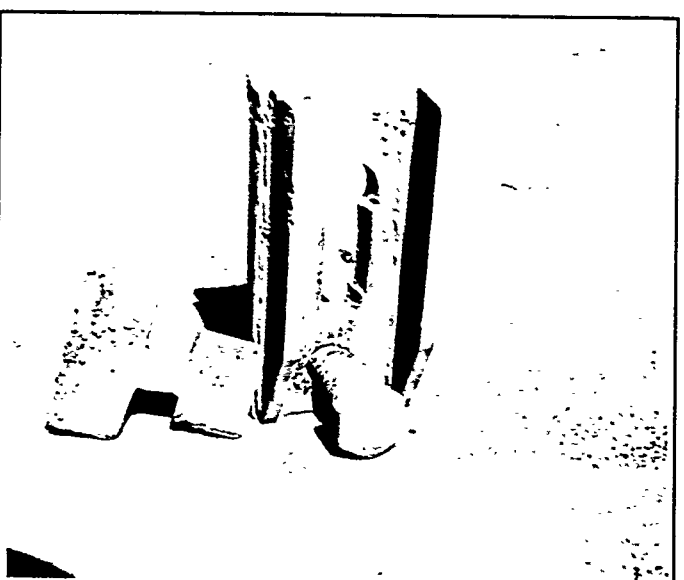
5.3a-9. Enerpac fairing tool used on shell seam



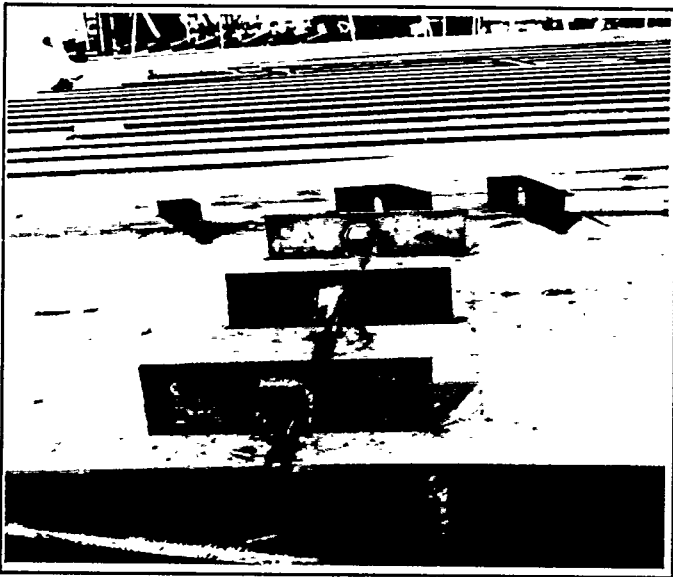
5.3a-10. Enerpac fairing tool



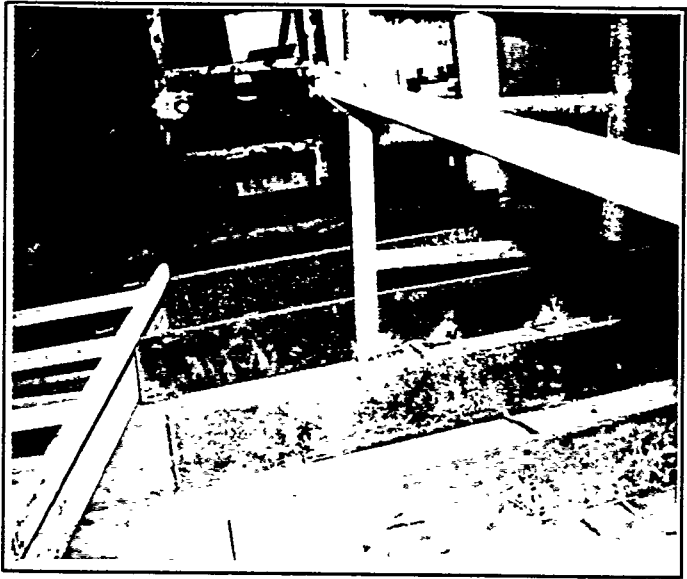
5.3a-11. Home made jacking clamp



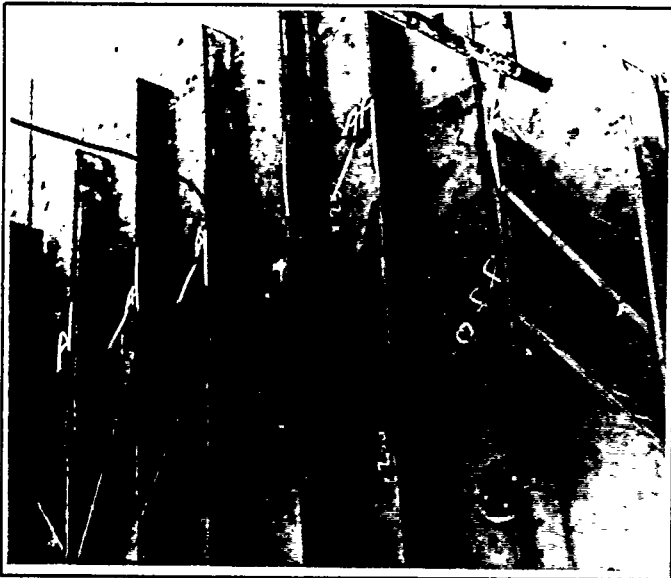
5.3a-12. Home made jacking clamp



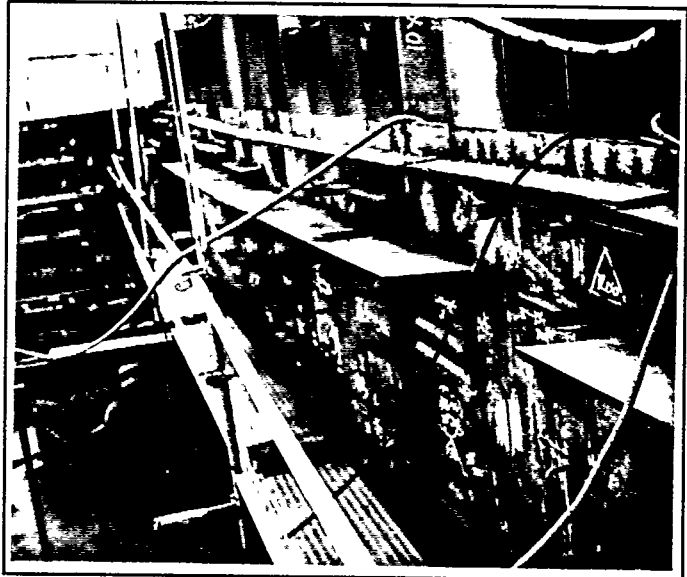
5.3b-1. Weld on strongbacks used on deck plating



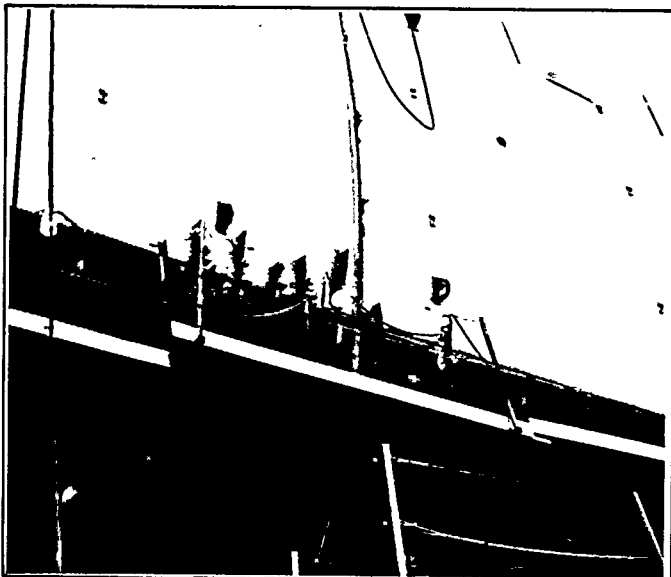
5.3b-2. Weld on strongbacks used on deck plating



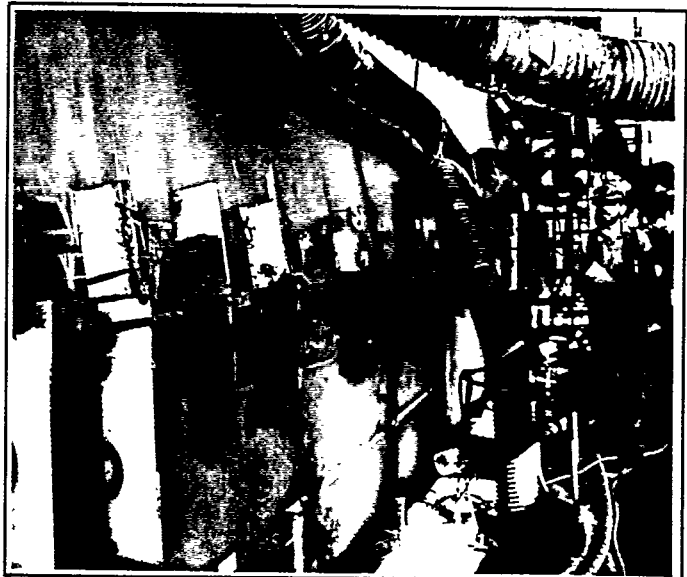
5.3b-3. Weld on strongbacks used on deck plating



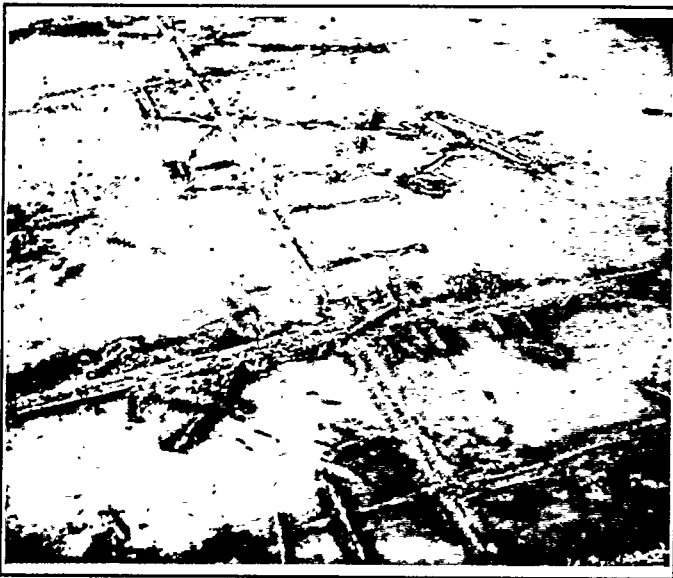
5.3b-4. Weld on strongbacks used on bulkhead plating



5.3b-5. Weld on strongback used on side shell



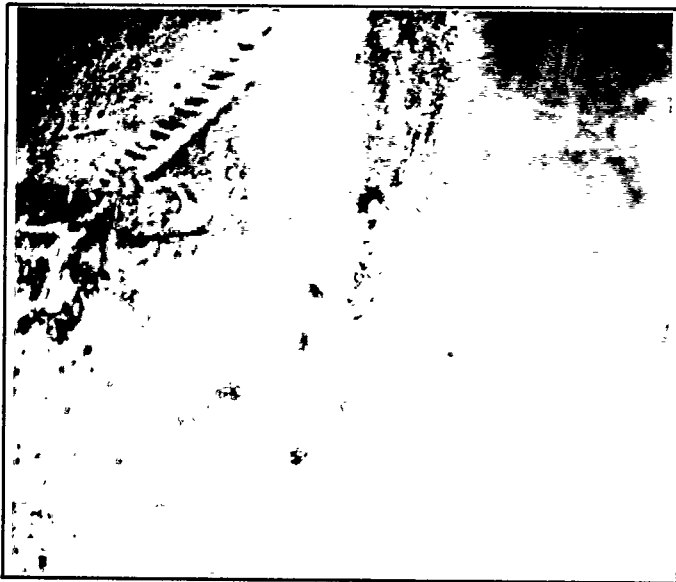
5.3b-6. Weld on strongback used on bulkhead plating.



5.3b-7. Appearance after strongback removal



5.3b-8. Gouging in way of strongback removal



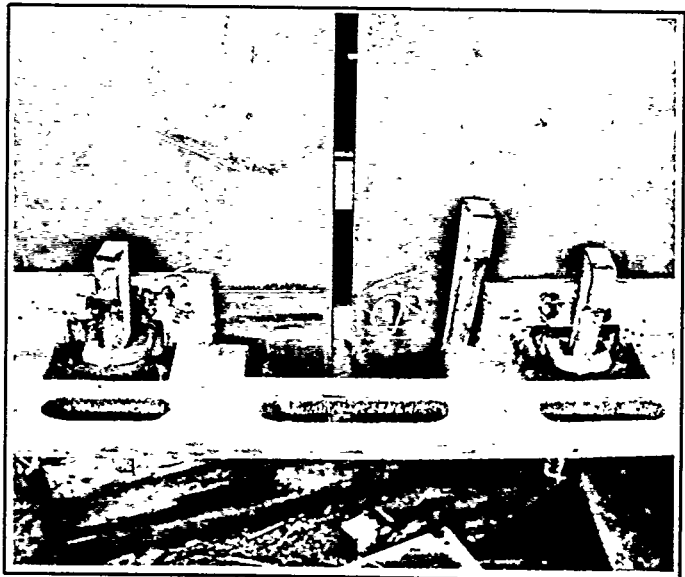
5.3b-9. Gouging in way of strongback removal



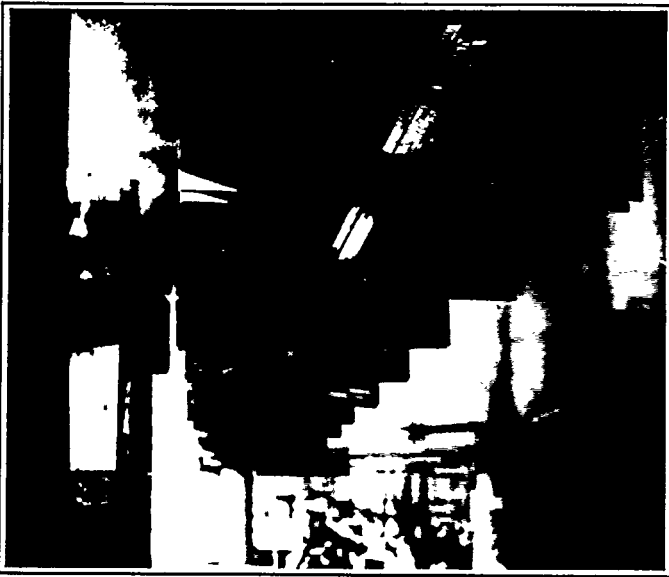
5.3c-1. Reusable strongback used on built-up angle



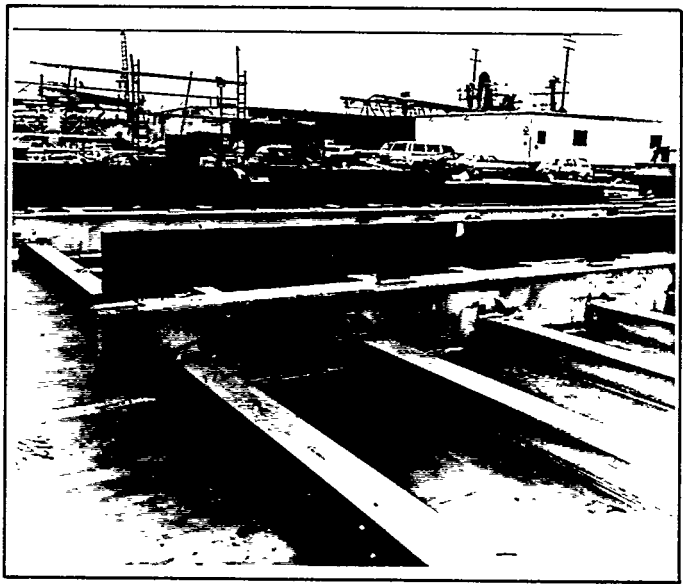
5.3c-2. Reusable strongback used on plating



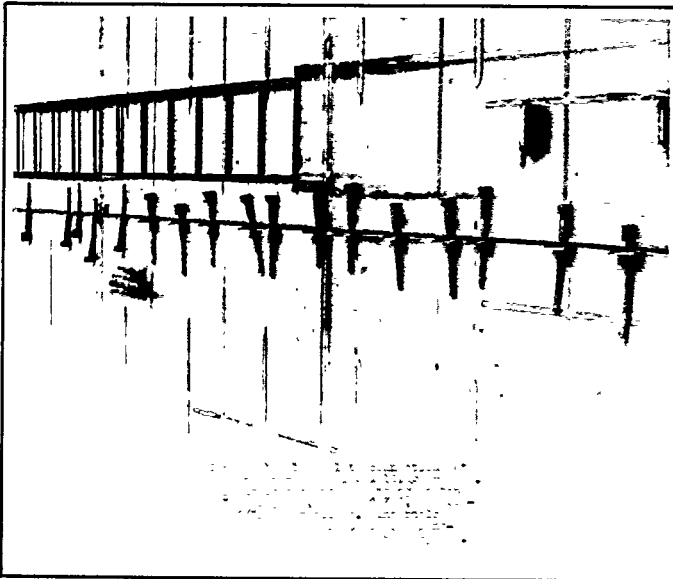
5.3c-3. Reusable strongback holds plating and back-up for electro-gas welding



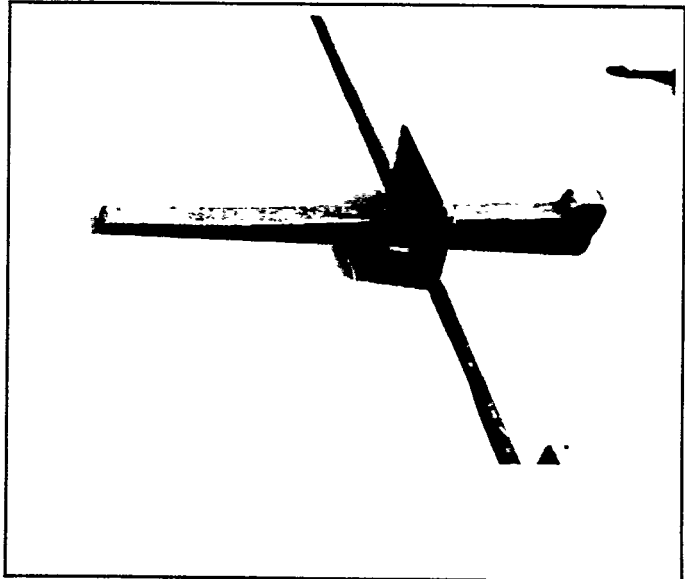
5.3c-4. Reusable strongback bolted on bottom plating



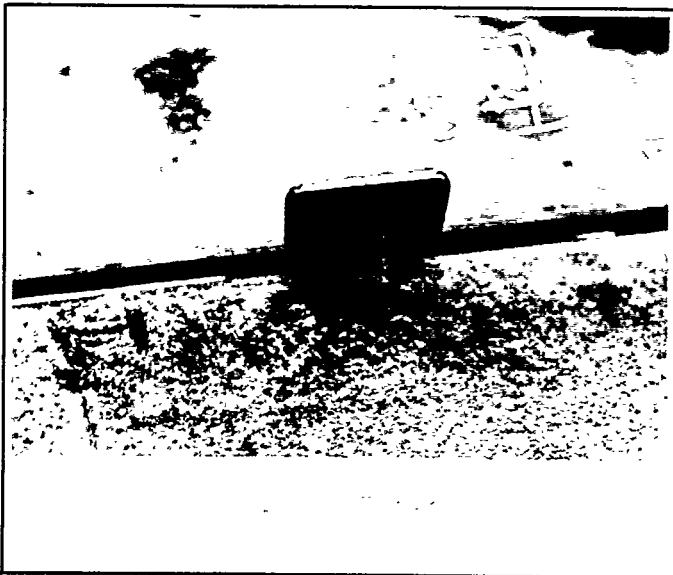
5.3c-5. Reusable strongback used on aluminum web-frame



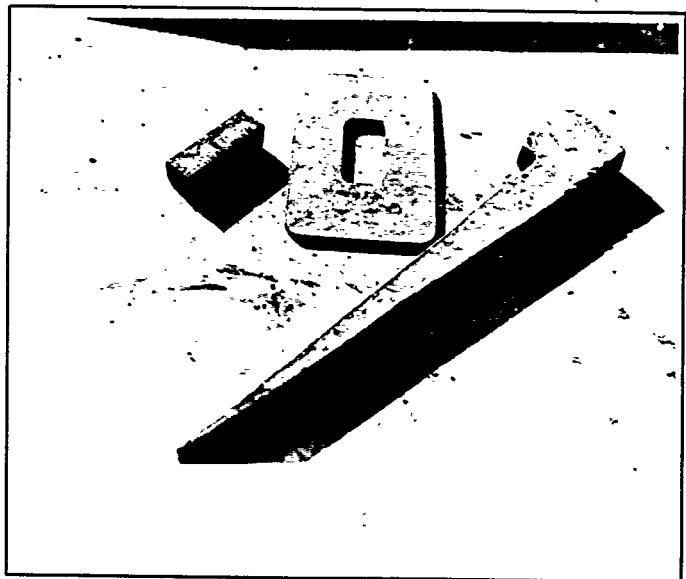
5.3c-6. Long wedge and yoke used in conjunction with ceramic backing weld process



5.3c-7. Wedge and yoke or clip



5.3c-8. Yoke or clip with square bar

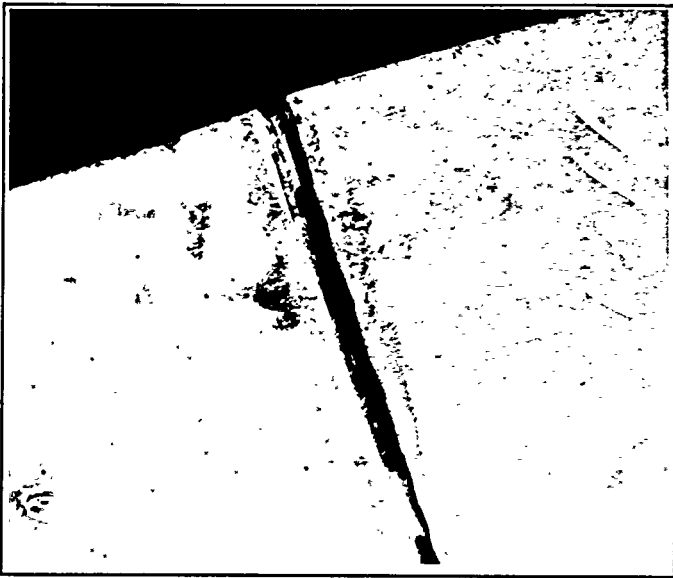


5.3c-9. Wedge, yoke or clip and square bar



## **5.4 Improper Fitting and Distortion**

Improper fitting, which includes excessive weld joint gap, inconsistent gap, incorrect weld joint geometry, misalignment, rough edge preparation and dirty or contaminated weld joints, will increase the costs for welding, fairing and rework. Fitting and fairing aids are tools which can be misapplied and misused, as with any tool. The workmanship of the user of these aids is the ultimate factor in producing quality fitting. Improper fitting tends to increase the need for fitting and fairing aids and the requirement for more specialized aids as the fabrication process continues toward completion. Distortion can be the result of poor storage and handling, cutting, shaping, fitting, welding and heat treatment. Several fitting and fairing aids are primarily methods or devices used to control distortion. These include flame straightening, strongbacks and weld sequencing. Distortion increases rework costs and detracts from the quality of the product.



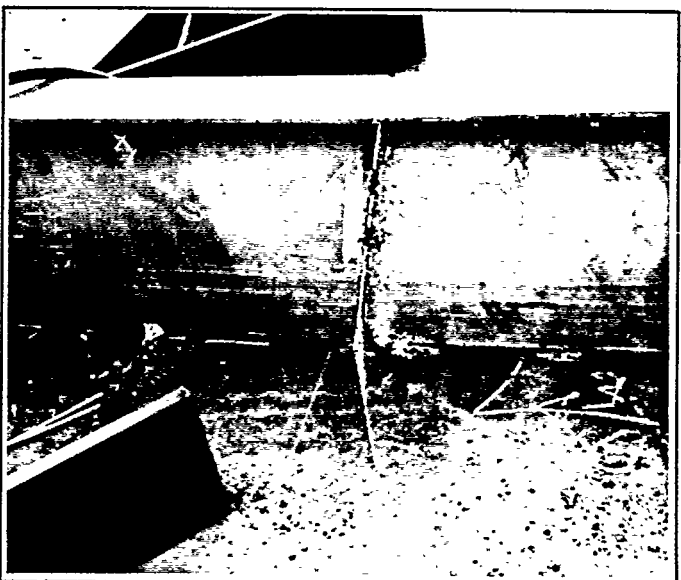
5.4-1. Poor edge preparation



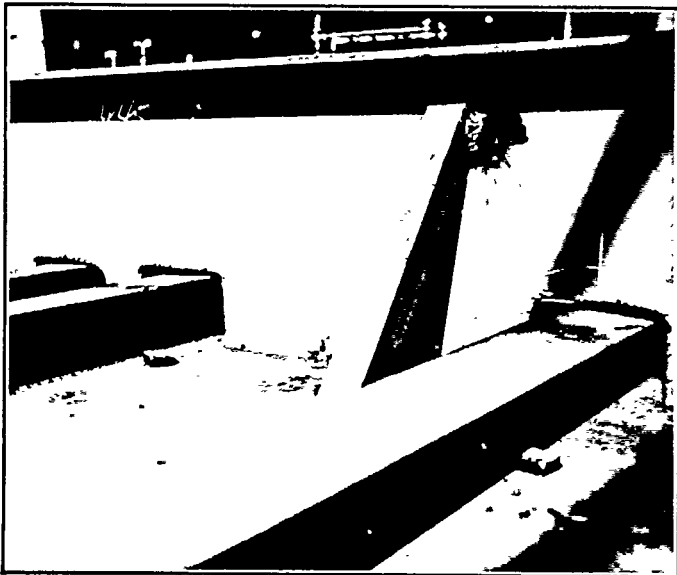
5.4-2. Excessive root opening



5.4-3. Excessive root opening



5.4-4. Inconsistent root opening



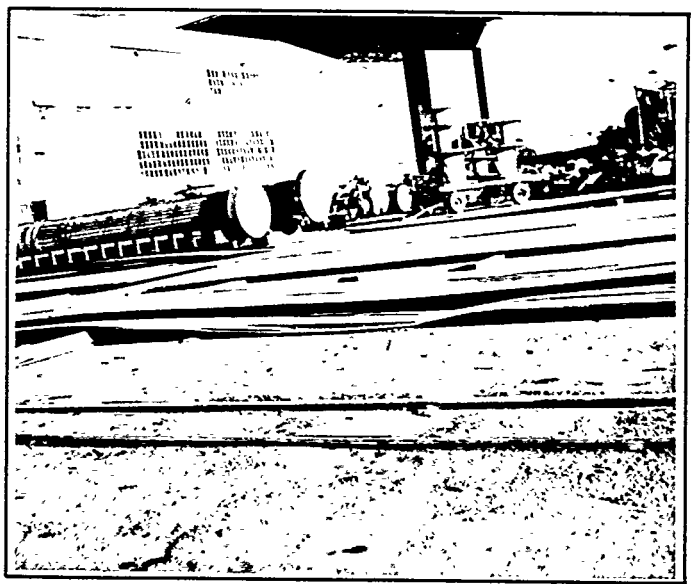
5.4-5 Excessive clearance in way of stiffeners



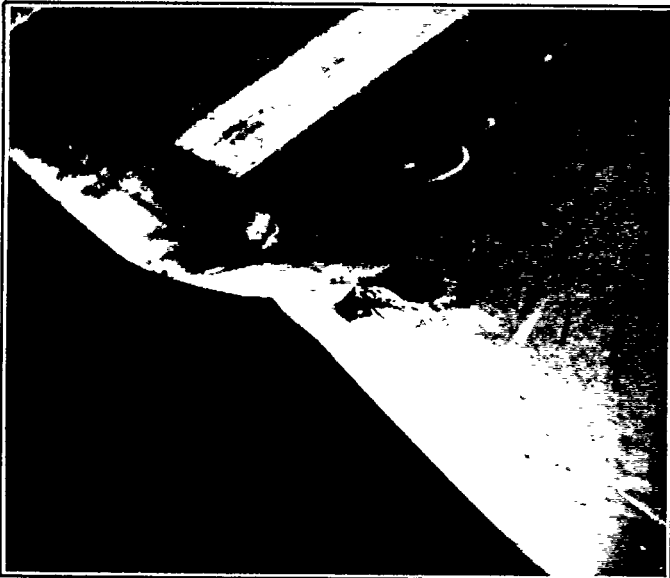
5.4-6. Excessive root opening



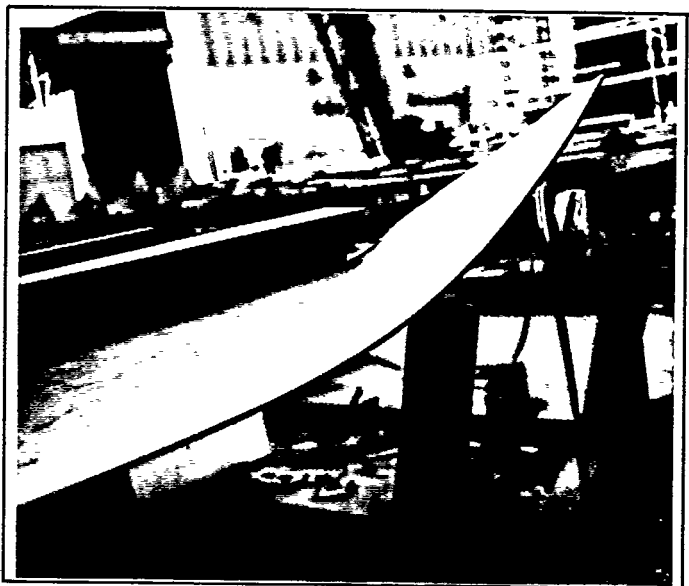
5.4-7. Distortion caused by truck wheels



5.4-8. Distortion caused by forklift wheels



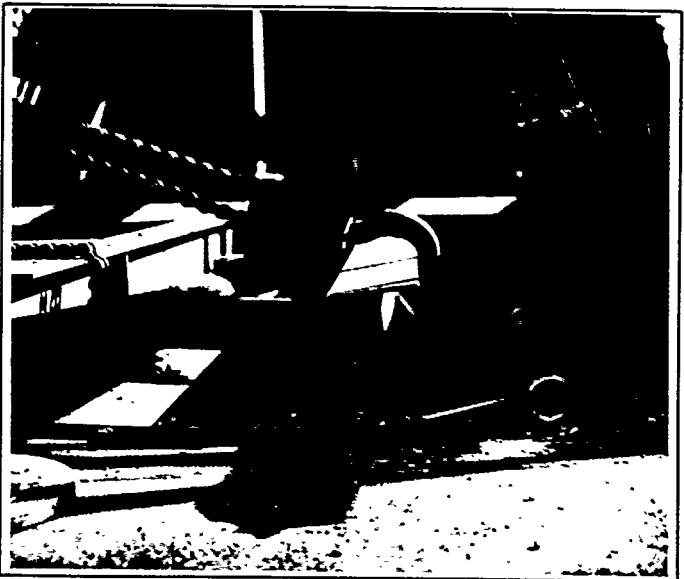
5.4-9. Distortion caused by improper handling



5.4-10. Distortion caused by improper handling



5.4-11. Distortion caused by excessive heat input



5.4-12. Distortion caused by improper use of tools

## **5.5 Fabrication Other Than Shipbuilding**

There were several devices which were documented in other sections of this report which fabricators other than shipbuilders are using. These are the reusable strongback, yoke and pin, jigs and fixtures. Most of the fabrication facilities visited employed a large quantity of specialized jigs and fixtures to produce high volumes of parts and assemblies. Few, if any, of these jigs and fixtures had relevance to shipbuilding, and were therefore excluded.

## **6.0 ACCURACY CONTROL AND FITTING AND FAIRING AIDS**

Accuracy control, also known as statistical quality control, and the use of fitting and fairing aids, seem to be used in direct proportion. The more control imposed on materials, parts, subassemblies, assemblies, and dimensional accuracies of units, the less fitting and fairing aids are used. Through the use of accuracy control, many dimensional deviations can be monitored and controlled. This provides the shipbuilder with a tool for predicting and correcting problem areas which would normally require the use of fitting and fairing aids at some later stage to correct. If one looks at accuracy control as a fitting and fairing aid, it would then be one of the most profitable aids any shipbuilder could employ. This aid also yields much information concerning labor, material, process and operational costs which may be used to further benefit a shipyard's productivity.

## **7.0 COST COMPARISON AND DEVELOPMENT**

Several fitting and fairing operations were selected for a cost comparison. These operations represent some areas where costs can be decreased by the use of better fitting and fairing aids (see Figure 2). Further cost comparisons were impossible due to the unavailability of data required to make reasonably accurate reports. Because there is a wide variation from shipyard to shipyard in the kind of aids used and the location of their use, each yard must evaluate its needs and goals in relation to costs. There are two areas of development which are noted as being particularly effective in reducing costs. The development and use of reusable aids for fitting and fairing can increase the efficiency of these operations and reduce scrap and replacement costs. Reusable aids are also less costly to use since many of them do not require grinding or arc gouging to remove and subsequent grinding and inspection on the workpiece. The development of standardized aids reduces the number of aids stocked, stored and handled and helps to improve housekeeping in the shipyard by having aids marked and stored in an organized manner. When aids are organized well, workers spend less time finding and returning these tools to and from their work areas. These two areas of development can be applied to many of the fitting and fairing aids currently being used and are seen as good starting points for reducing costs and supporting Group Technology.

## Fit-up Method Cost Comparisons

### 1. Plate to Plate

The following-are estimated hours/costs to fit-up a 40' butt using three different methods:

Method	Fit-Up <sub>1</sub>	Clean-Up <sub>2</sub>	Combined Costs <sub>3</sub>
Dog & Wedge	5 hrs.	1 hr.	\$180
Magnet	3 hrs.	---	\$ 90
One Side Welding	1/2 hr-	---	\$ 15

Notes:

1. Joining 1/2" thick plating.
2. Includes welding and grinding of scars as required.
3. \$30 per hour labor costs.

### 2. Stiffener to Plate

The following are estimated hours/costs to fit-up and clean-up stiffeners to plating:

Method	Fit-up,	Clean-Up <sup>2</sup>	Combined Costs <sub>3</sub>
Dog & Wedge	8 hrs.	1½ hrs.	\$285
Magnetic Saddle	5 hrs.	---	\$150
Automated Stiffener Placement	24 min.	---	\$ 12

Notes:

1. 4-40' stiffeners.
2. Includes welding and grinding of scars as required.
3. \$30 per hour labor costs.

Figure 2. Fit-Up Method Cost Comparisons

### 3. Unit to Unit Erection

The following are estimated hours/costs to prepare 40' of an erection butt

Fit-Up Method	Fit-Up <sub>1</sub>	Clean-Up <sup>2</sup>	Combined Costs <sub>3</sub>
Dog, Wedge & Strongback	32 hrs.	20 hrs.	\$1560
Stud Welded Strongback	24 hrs.	11 hrs.	\$1050
Yoke, bull-pins & ceramic backing	4 hrs.		\$ 120

Notes:

1. Joining  $\frac{3}{4}$ " plating.
2. Includes welding and grinding of scars as required.
3. \$30 per hour labor costs.

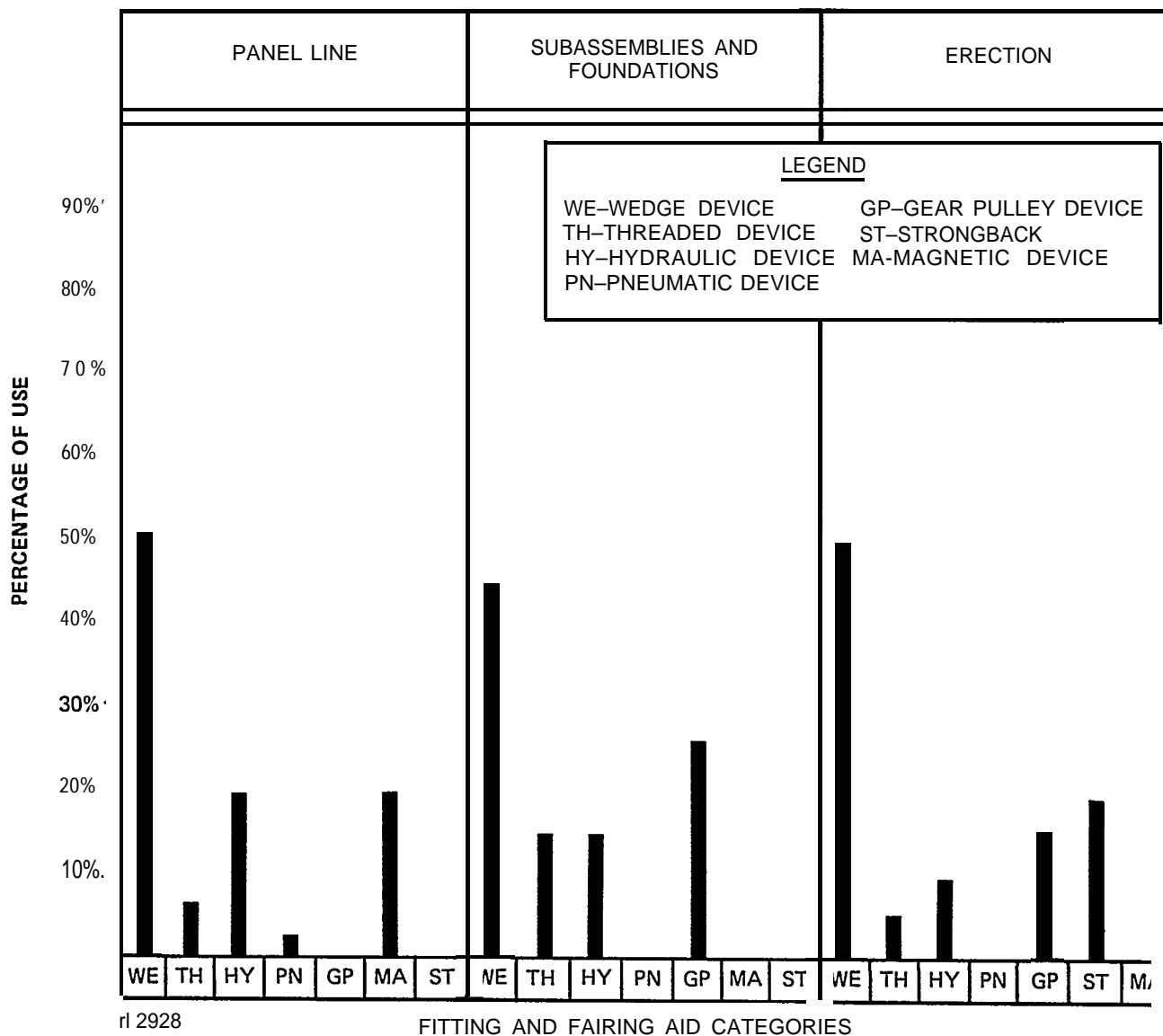
Figure 2. Fit-Up Cost Comparisons

## 8.0 RESULTS AND RECOMMENDATIONS

The observation and study of fitting and fairing methods, techniques and devices used by U.S. shipbuilders have left the investigators of this report with the following conclusions. First, other than a few isolated applications, fitting and fairing aids have changed very little since the 1940's. Second, the implementation of more automated and faster fitting and fairing aids will be defeated if closer control of material and fabrication tolerances is not initiated and maintained. Third, the use of accuracy control to support Group Technology will influence which fitting and fairing aids are used and should provide a system for determining which aids are more productive at each area and stage of fabrication. Many of the devices currently available commercially are being underutilized or disregarded altogether. This is not to say that no further development in fitting and fairing aids should be pursued. Fitting and fairing aid technology, however, is available today to support Group Technology. An overall percentage of use chart is given in Figure 3. This then shows the percentage of use for each category of fitting and fairing aid with respect to the different phases and areas of fabrication in U.S. shipbuilding.

To answer the question of what needs to be done to improve fitting and fairing in U.S. shipyards, it is again mentioned that accuracy in materials and fabricated parts and assemblies is paramount. To accomplish this, several recommendations are given for further consideration and action.

- 1) An accuracy control implementation manual for managers is seen as an immediate need.
- 2) Standards should be developed for shipbuilding fabrication to support accuracy control in every zone, area and stage of fabrication.
- 3) The tools required for meaningful measurement of ship components to support accuracy control need to be defined, documented and developed.
- 4) A shipbuilders' material purchase specification with close control of dimensional requirements that reflects the needs born out of accuracy control used in Japan, should be assimilated. Problem areas need to be identified and purchase specifications for these areas compared to Japanese standards. Once excessive dimensional tolerances are identified, material purchase specifications or addendums should be written. There were several comments concerning excessive dimensional variations in plate and shapes that met purchase specifications (e.g., ASTM and MIL-Specs. ) during yard visits. This indicates that purchase specifications at present do not altogether comply with shipbuilding requirements.
- 5) In areas and/or stages which do not lend themselves to automation, such as out-of-flow work and erection of assemblies, development of traditional fitting and fairing aids is needed. There are numerous companies offering equipment to automate panel lines, pipe shops and cutting systems, but few were found that offer improvements on traditional aids used on curved assemblies, on-unit and erection.
- 6) All shipyards and many other industries use heat or flame straightening as a fairing tool, however, there is little written on this subject. A practical manual for shipyards of methods, techniques and practices successfully used is needed to remove some of the mystery associated with the use of this tool.
- 7) A general observation concerning fitting is that fitting personnel do not understand the need for producing good quality, low cost welds. This needs to be remedied through training programs. The development of a training program for both fitters and welders may have to be addressed on an individual yard basis because of unique craft structuring.



- NOTE: 1). SPECIALIZED DEVICES REPRESENT A VERY SMALL PERCENTAGE OF USE AND WERE INCLUDED IN THE CATEGORY WHICH CORRESPONDS WITH THEIR PRIMARY METHOD OF MECHANICAL ADVANTAGE.
- 2). PADEYES, STAYS AND CABLES CATEGORY AND JIGS, MOCKS AND FIXTURES CATEGORY WERE NOT INCLUDED BECAUSE OF DUAL PURPOSE USE OR LACK OF DATA.

Figure 3. Fitting and Fairing Aids by Percentage of Use in U.S. Shipbuilding